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Genetic analysis of autonomic reactivity to psychologically stressful situations☆

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Abstract

We present the results of a behavioural genetics study on response profiles of autonomic measures (heart rate, blood pressure, and galvanic skin level), under ecologically valid, stressful conditions. Where response profiles of different physiological variables are the object of study, and when daily life stressors are taken into account (Turner and Hewitt, Annals of Behavioral Medicine, 14 (1992) 12–20), autonomic responsiveness to psychological stressors is thought to be an inherited trait. The participants were 100 female twin pairs, 57 monozygotic and 43 dizygotic twin pairs. Participants watched eight films with a stressful social content while autonomic measures were continuously recorded. Results show that the heritability coefficients of response profiles of autonomic measures are almost twice as high as that of single variables. The results further show that genes exert their influence on physiological behaviour not only directly, but also indirectly, by influencing the idiosyncratic relation between a person and his environment.

Keywords: Genetics; Heritability; Person × situation interactions; Physiological response profiles; Cardiac reactivity

☆ The results presented in this paper are part of a more extensive research project on the 'Seven Turtles'—model of Zuckerman (1992, 1993), performed at Tilburg University, The Netherlands, as part of a PhD-research project (Lensvelt-Mulders, 2000).

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1. Introduction

Although it is widely assumed that autonomic responsiveness to psychological stressors should be more than moderately heritable, there is little empirical evidence for this premise to be found (Turner and Hewitt, 1992). Research on the heritability of cardiovascular reactivity to psychological stressors revealed that autonomic responsiveness to stressful events is only moderately heritable (Rose, 1992; Ditto, 1993). However the evidence is not conclusive. For instance most of the work covered by Turner and Hewitt's review article was done on heart rate reactivity and blood pressure changes in relatively small groups, with exclusively male respondents. Turner and Hewitt (1992) therefore suggested that a wider range of physiological variables should be incorporated in future studies, and to search for functional combinations of these variables. The idea that functional combinations are the better object of physiological study than single physiological variables is actually not new within psychology. Several functional covariations between heart rate and blood pressure have already been described (Lacey and Lacey, 1978; Mulder and Mulder, 1981). Secondly, Turner and Hewitt proposed using more ecologically valid psychological stressors to induce stress instead of artificial stressors like the cold pressure test.

In this paper we present a study of the genetic and environmental effects on autonomic responsiveness to psychological stressors for single physiological variables and functional combinations of these variables. In addition autonomic responsiveness will be studied under different stressful situations to illuminate the relation between the effects of the genotype and the effects of the topic situation.

In our laboratory the research program is primarily focussed on the behavioural consequences of stressful events as they appear in daily life situations. As stimuli we use films featuring such situations, while autonomic physiological reactions are monitored continuously in subjects watching these films (Hettema et al., 1989a). Autonomic reactivity, recorded while respondents are watching these films, is affected by the individual's specific response potential and the influence of the situation to elicit these autonomic responses (Vingerhoets, 1985; Hettema et al., 1989b; Geenen, 1991; Hettema, 1994; Manuck, 1994).

A second feature of the research program is the use of multiple physiological indicators of stress to identify meaningful response profiles (Hettema et al., 1989b,c, 2000; Geenen, 1991). Seven physiological measures were selected (Geenen, 1991). Heart rate (IBI, inter beat interval) and systolic and diastolic blood pressure (SBP and DBP) are used to reflect cholinergic and adrenergic activation and baro receptor activity (Larsen et al., 1986). Skin conductance levels (GSL) are used to measure sympathetic and cholinergic activity. To allow discrimination between these different systems the *T*-wave amplitudo (TWA) and pulse transit time (PTT) were added as measures for beta-adrenergic activity. And finally fingertip temperature (FTT) is monitored as a measure for sympathetic autonomic nervous system activity.

Response profiles were computed following the regression equations identified earlier by Hettema et al. (2000). They computed composite scores using a four steps analysis. First, patterns of reactivity were computed and differentiated from patterns of non-reactivity. Secondly, the number of patterns was reduced to 100 pattern clusters according to Ward's method. In a third step, these pattern clusters were submitted to ALSCAL for multidimensional scaling to derive the major dimensions accounting for the patterns. The elbow criterion suggested a three dimensional solution (minimum stress 0.07 and multiple correlation 0.99). Finally, in step four we established the regression equations of these ALSCAL dimensions on the separate measures. These regression equations were used to compute a respondent's individual response profile per film:

Response profile 1: Dissociation between Cardiovascular and GSL activity

$$-0.22 + 0.15\ \mathrm{IBI} + 0.05\ \mathrm{PTT} + 0.37\ \mathrm{GSL} + 0.17\ \mathrm{FTT} - 0.05\ \mathrm{DBP} - 0.05\ \mathrm{SBP}$$

This response profile is based on the dissociation of heart rate reactivity and blood pressure changes on the one hand and galvanic skin level at the other. It should be noted that IBI is a measure for heart rate, and that a higher IBI is indicative for a lower heart rate.

Response profile 2: Dissociation of Cardiac and Vascular activity

$$-0.15 + 0.17\ \mathrm{IBI} + 0.17\ \mathrm{TWA} - 0.15\ \mathrm{PTT} - 0.09\ \mathrm{FTT} + 0.23\ \mathrm{DBP} + 0.21\ \mathrm{SBP}$$

The second response profile clearly shows a dissociation between heart rate reactivity and blood pressure changes. When heart rate accelerates blood pressure falls and vice versa.

Response profile 3: Covariation of Cardiovascular and GSL activity

$$0.51 + 0.17\ \mathrm{IBI} + 0.14\ \mathrm{TWA} + 0.22\ \mathrm{PTT} - 0.16\ \mathrm{GSL} + 0.4\ \mathrm{FTT} - 0.19\ \mathrm{DBP} - 0.18\ \mathrm{SBP}$$

The third response profile reflects a covariation between the cardiovascular reactivity and galvanic skin level measures. When cardiovascular measures rises, electrodermal measures rise to.

These three response profiles proved highly consistent over situations and over time, as demonstrated with generalisation coefficients exceeding 0.80 for each dimension (Hettema et al., 2000).

2. Purpose of this study

Two hypothesis were put to the test in this study:

2.1. Hypothesis 1: Autonomic response profiles will reveal larger genetic effects than the single autonomic variables

Because response profiles reflect underlying functional patterns of autonomic behaviour, the correlation between twin pairs is not dependent on the direction of the autonomic reactivity. When only single variables are taken into account, differential reactivity between two twin halves will reduce the intra class correlation (ICC). When differential reactivity is part of the expression of the same response profile, the ICC will increase.

2.2. Hypothesis 2: The idiosyncratic relation between a person and his/her environment ($P \times S$) is an heritable trait

This is already suggested by Eaves and Eysenck (1976) (Eaves and Young, 1981) and in line with Plomin's theory of the existence of gene-environment correlations (Plomin et al., 1977). To test this hypothesis, the genetic effects on the interaction between person and different stressful situations are studied.

3. Method

3.1. Participants

A group of 100 adult female twin pairs (age 18–47, mean 31.5) participated in the study. Twins were recruited with the aid of the media and the Dutch Twin Association. Twins came to the laboratory in pairs, one pair each day. An experimental session ran from 9.30 am until approximately 16:00 h. All subjects were paid FL 80.- ($40) and a free lunch for their participation. Subjects were asked to abstain from drinking alcohol and excessive amounts of coffee and tea after 11:00 h on the previous day.

Participants were divided into two groups of 57 monozygotic (MZ) and 43 dizygotic (DZ) twins. Because of the high error susceptibility of physiological research, only 56 MZ and 37 DZ twin pairs finished the physiological measurements. One MZ twin pair and three DZ twin pairs had to be discarded from the physiological analysis because of apparatus failure. Two DZ twin pairs had to be discarded because one of the participants had a serious ventricular sinus arrhythmia. One DZ twin pair had to be discarded because one of them became ill during measurement. For 12 twin pairs zygosity was determined before they came to our laboratory by blood- and DNA typing. Zygosity in the other twin pairs was determined by means of a questionnaire consisting of items about physical similarity, and frequency of confusion by significant others. Agreement between zygosity based on blood typing versus questionnaires is approximately 95% (Loehlin, 1992). Twenty-three twin pairs had previously participated in scientific research, the other 77 pairs were unfamiliar with research procedures.

It was not necessary to control for differences in circadian rhythm, because morningness and eveningness are associated with base levels of autonomic parameters, and not with differences in autonomic reactivity (Mecacci and Rocchetti, 1998). There are no reports that the autonomic measures we used were not autosomal heritable, so correction for female twin pairs was also unnecessary (Lensvelt-Mulders, 2000).

3.2. Materials

A major feature of this study is the use of ecologically valid psychological stressors to induce daily life stress. For this purpose we used a film technique developed by Hettema et al. (1989a). Special films were made in what is called an ecologically valid fashion (Hettema et al., 1989a), which means that they are not, like feature films, supported by music and/or camera effects to evoke the desired emotions. Films were made from the observer's point of view, where the camera takes over the spectator's eye movements. In this type of research subjects are put in front of the films and autonomic measures are recorded continuously. The use of films as a method to evoke autonomic reactivity has been studied in earlier research (Hettema et al., 1989a,b; Vingerhoets, 1985; Geenen, 1991; Leidelmeijer, 1991).

In this study nine films were used including one buffer film.

First the film '*Party*' was shown as a buffer film to relax the participants and to give them the opportunity to become familiar with the physiological apparatus. The content of the eight experimental films can be briefly described as follows.

3.2.1. Divorce

After a quarrel the night before Mr A tells his wife that he is going to see a lawyer. He wants a divorce. Her bitter reply is that she will do the same. They both tell their story to their lawyers. At the end Mr A picks up his belongings, kisses the children, and drives away.

3.2.2. Failure

M has to undergo an oral examination, but on almost every question she fails to give the correct answer. On top of which the examiners' conduct makes her very nervous. After a while she is dismissed.

3.2.3. Rapprochement/advances

Mr M works in a building opposite the music school. Looking out of the window he falls in love with a cello teacher. He approaches her by telling her that he wants to resume his cello lessons. He borrows an instrument of a friend and tries to draw some acceptable sounds out of it, which annoys the neighbours. When he shows up at her place he has to make two confessions: the first that he never played the cello before, and second, that he has fallen in love with her.

3.2.4. Intrigue

One evening, Mr S is told that the manager of his department will be promoted, leaving a vacancy to fill. His wife suggests that he should move against his competitors.

3.2.5. Quarrel

When Mr and Mrs F return from an office-party she is very angry because her husband spent too much time with his secretary. She is also furious at the flagrant behaviour of his boss and she blames her husband for a spoiled evening. He accuses her of being narrow-minded.

3.2.6. Interruption

Garage owner R asks his mechanic to repair Mr W's car as a priority. He himself has an appointment and cannot help. The mechanic starts working on the car but progress is hampered by interuptions from customers, telephone calls, the wrong tools and so on. Some hours later his boss returns and informs him that Mr W does no longer need his car, he almost explodes.

3.2.7. Gossip

At about 4 o'clock, Mr K a high school teacher, walks to his car. There he is welcomed by an attractive young girl, who kisses him. Two of his colleagues watch this scene. That day Mr K and the girl are seen in several public places. The next morning Mr K is told that the headmaster wants to see him immediately, because an intimate relation between teacher and pupil is taboo.

3.2.8. Love-play

A young man with a cut out ad for a tent in his hand, rings at a door. He looks very surprised when the door is opened by a girl he already knows. She has just moved in and he helps her placing the furniture. Then they talk about the tent. He needs it for his holidays in Greece. After a while he suggests she should come with him. She is delighted and accepts his offer. He accepts her invitation to stay with her that night.

3.2.9. Apparatus

Films were projected by means of an Ernemann VIII film projector, on a large screen (3.14×1.8 m). Sound was amplified with a Sansui AU-66-audio amplifier. To maximise the impact of the films, participants were seated in a comfortable chair in a one person cinema. Music and sound came from two Phillips speakers, type 22RH497, aside the film screen. Temperature in the cinema was kept constant at 22 °C. Autonomic reactions were monitored continuously throughout the whole session.

The films were presented to all subjects in the same sequence as that given above, and alternated with a four minute rest period during which relaxing music was played. This was done for two reasons. It was necessary to give the autonomic

arousal, elicited by the film, time to return to baseline level, and the data sampled during the rest periods are necessary to correct for time trends (Geenen, 1991).

3.3. Recording autonomic measures

For ECG recordings two Ag–AgCl-electrodes were placed on the left side of the abdomen and the right clavicle and one, the ground electrode, was placed on the left under arm. The signal was amplified with a Beckman HP 396a amplifier, high pass filter 0.3 RC, low pass 30 Hz, sample frequency 1000 Hz. The IBI and the T-wave amplitude were taken from the ECG-signal.

The T-wave was defined as the maximum amplitude between 150 and 300 ms after the R-top, minus the extrapolated zero level of the ECG signal, determined as iso-electric midpoint of the PQ interval (Geenen, 1991; Melis, 1997).

Pulse transit time (PTT) was measured with the aid of a Hewlett and Packard photo electric densitograph, placed on the left ear-lobe. Signals were amplified using a plesmythogram amplifier (NIM). PTT was defined as the time between R-top and maximum blood pulse in the left ear lobe.

Blood pressure was measured with the aid of an Ohmeda 2300 Fin-a-press blood pressure monitor. This monitor provides continuous measurement of arterial blood pressure. The finger cuff was placed on the left phalanx finger. SBP and DBP were derived from this signal as the maximum and the minimum reading of the monitor.

The galvanic skin level (GSL) was measured using a GSL-coupler, LP 15 Hz, ($RC = 0.15$). The output signal was amplified to 2.5 V. Ag–AgCl electrodes were placed at the right foot (Boucsein, 1992).

The FTT was recorded using a thermocouple, the Tempcontrol, P550, with standardised output. The transducer was attached to the right middle finger.

Physiological measures were sampled continuously, at 1000 Hz, during films and rest periods. A computer program was written to prepare the data for analysis, converting all data into the desired units of measurement, mmHg for blood pressure, IBI and PTT in ms, GSL in μΩ, TWA in μV and FTT in °C.

4. Analysis

4.1. Scoring

First *a data reduction protocol* was applied to convert raw data into reactivity scores. Our data were corrected for base-level changes and time trends with a three steps curve-fitting procedure derived from a procedure by Geenen (1991) (Melis, 1997; Lensvelt-Mulders, 2000). The main assumption of this procedure is that time trends are monotonically increasing or decreasing functions. For each physiological measure average scores were computed for each subject, for successive periods of 30 s. In addition average scores per subject per single variable and response profile were obtained for each third minute of the 4 min resting condition between films. Time curves were subsequently fitted to the average scores for each subject during

rest conditions. Unstandardised reactivity scores were computed as the difference between the monitored score and the expected score based on the rest condition curve. These unstandardised scores were divided by individual standard deviations of the values during the resting periods to yield reactivity scores (Geenen, 1991; Hettema et al., 2000). Table 1 shows the results of this data reduction analysis per film.

4.2. Genetic analysis

In order to analyse the differential contribution of genotype and environment on individual differences, data are needed from genetically informative individuals.

The twin design is based on the notion that there are two kinds of twins, the monozygotic (MZ) or identical twins and the dizygotic (DZ) or fraternal twins. Since identical twins share 100% of their genes they are of the same genotype, all differences between them are assumed to be environmental in origin. Fraternal twins share an average of 50% of their genes. By comparing the phenotypic similarity of identical twins with that of fraternal twins, we conduct a natural experiment to investigate the effects of heredity and environment on behaviour. If identical twins are about twice as similar on a trait as fraternal twins, this is a strong indication that an observed trait is influenced by genetic factors (Plomin et al., 1990; Boomsma, 1992; Loehlin, 1992; Bouchard, 1993; McGraw and Wong, 1996).

Quantitative genetic analysis (QGA) has become the standard procedure to analyse twin data (Boomsma and Gabrielli, 1985; Heath et al., 1989; Neale and Cardon, 1992).

Table 1
Values of single autonomic variables

Variables	IBI	SBP	DBP	PTT	TWA	FTT	GLS
Means and S.D.							
	885.6	139.5	83.4	208.8	5.2	32.8	12.9
	125.6	16.0	10.6	21.7	1.9	2.6	7.6
Reactivity scores							
Film1	−0.0292	−0.12	−0.33	−0.74	−0.17	0.95	−0.026
Film2	0.570	−0.16	0.31	−0.40	0.096	1.08	0.140
Film3	0.390	−0.36	−0.79	−0.32	−0.14	1.25	0.054
Film4	0.431	−0.55	−0.83	−0.18	0.062	1.43	0.56
Film5	0.47	0.002	−0.19	−0.10	0.13	1.53	0.34
Film6	0.18	−0.23	−0.50	−0.67	−0.25	1.09	−0.064
Film7	0.20	0.18	0.004	−0.54	−0.006	0.94	0.76
Film8	1.06	−0.22	0.11	−0.16	0.73	0.88	0.66

Abbreviations: IBI, inter beat interval in ms; PTT, pulse transit time in ms; TWA, T-wave amplitude in μV; SBP, systolic blood pressure in mmHg; DBP, diastolic blood pressure in mmHg; FTT, finger tip temperature in °C; GSL, galvanic skin level in μΩ.

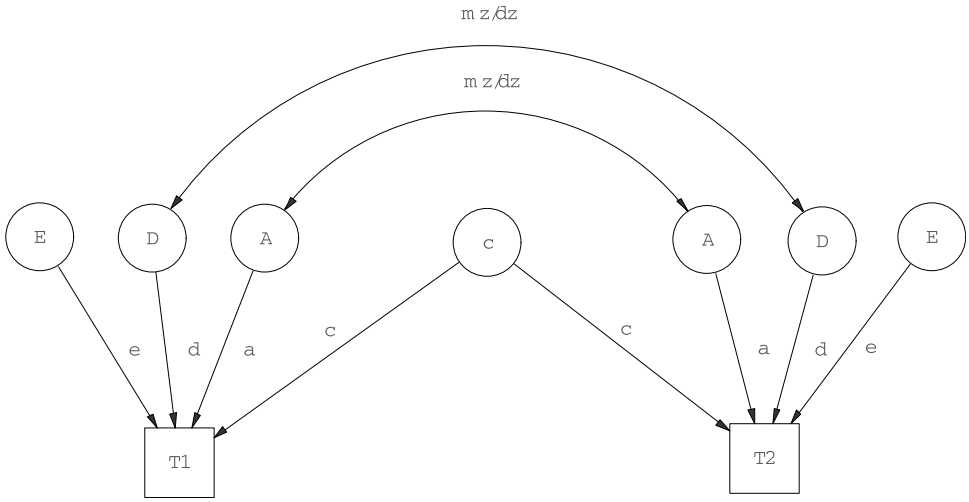

Fig. 1. Path model for MZ and DZ twin pairs, where $T1$ and $T2$ are the members of a twin pair. E, unique environment; A, additive genetic effects; D, dominance effects; and C, common environmental effects. The paths e, a, d, and c are the effects of E, A, D, and C on the trait. The correlation between the MZ twins is fixed at 1 for A, D, and C. The correlation between DZ twins is fixed on 0.5 for A, 0.25 for D and 1 for C.

Fig. 1 presents the simple QGA-path model for twins reared together, the theoretical decomposition of genetic and environmental influences on the phenotype (Boomsma, 1992; Loehlin, 1992). The squares represent the observed variables, the phenotypic variance, where T1 and T2 are members of a twin pair. The variables in the circles are latent, not observable variables, they are defined on theoretical notions. 'A' stands for the part of the variance due to additive genetic influences, ' D' for variance due to dominance and epistasis effects, 'C' for the part of the total phenotypic variance due to the effects of the shared environment, and 'E' for the part of the variance due to effects of the unique environment, where random errors are by definition incorporated in 'E' (Loehlin, 1992). When twins are reared together, C and D become confounded, making it impossible to test a full ACDE-model. Therefore the models tested in the present study are:

the E-model: the data do not indicate any family resemblance,
the AE-model: family resemblance is caused by additive genetic effects,
the CE-model: family resemblance is caused by shared environmental effects,
the ACE-model: family resemblance is caused by additive genetic and shared environment effects, or the ADE-model: stating that family resemblance is caused by additive genetic and dominance effects.

As a rule of thumb, the ACE-model is tested when the (intraclass) correlation of MZ twin pairs (r_{MZ}) is less than twice the (intraclass) correlation between DZ twin pairs (r_{DZ}), i.e. when DZ twins are more alike than could be expected on the basis of their genetic relationship. When r_{MZ} is more than twice r_{DZ} the ADE-model will

be tested, i.e. DZ-twins are less alike then could be expected on a 50% genetic relationship.

A model with only genetic D effects (DE, DCE) is not expected on theoretical grounds, and therefore not tested (Neale and Cardon, 1992). Before applying this method to our data, three assumptions have to be made. It is assumed that gene-environment correlations and interactions are zero and that there is no assortative mating for the variables under study. The model also assumes equality of trait-relevant, environmental experiences among MZ and DZ twins, i.e. the so-called equal environment assumption (Rose et al., 1988; Plomin et al., 1990; Loehlin, 1992). We tested the equal environment assumption (EEA) on our data, and although we found significant differences between MZ-twin pairs with regard to shared environment, these differences did not seem to influence the traits under study (Lensvelt-Mulders and Hettema, 1996).

4.3. Analysis of the first hypothesis

Ideally, disposition or trait scores are a measure of aggregated, here physiological, behaviour across a representative sample of situations (Blalock, 1982; Van Heck et al., 1994). To test hypothesis 1 we aggregated the results across films, obtaining one mean score per subject, for IBI, SBP, DBP, GSL and the autonomic response profiles, and the reactivity scores for every film separately (Table 1). An extra advantage of the aggregation of results over situations is that we can compare our heritability coefficients for single variables with the results of earlier research.

Variance-covariance matrices were computed for MZ and DZ twins with the aid of SPSS 7.5, and univariate genetic structural equation models were fitted to these variance-covariance matrices. To fit the models the statistical package Mx (Neale, 1995) was used. Mx provides parameter estimates, a χ^2 test of the overall goodness of fit of the model.

4.4. Results

The intraclass correlations (ICC) for MZ and DZ twin pairs separately, and the results of the model fitting procedures are given in Table 2.

For most variables the AE-model was the best fitting model when tested against other models with the $\Delta\ \chi^2$ test. Only for response profile 1 (dissociation between cardiovascular and GSL measures) did the $\Delta\ \chi^2$ test yield a χ^2 difference above 3.841 ($df = 1$), indicating ADE to be the better model.

The heritability coefficients (h^2) are reported in the lower part of Table 2. For the single variables h^2 ranges between 0.28 for GSL and 0.42 for SBP, which corresponds with results from earlier behavioural genetic research (Turner, and Hewitt, 1992; Ditto, 1993). The h^2 for the response profiles are much higher, for the dissociation between cardiovascular measures and galvanic skin levels (profile 1) h^2 is 0.79 $(0.40 + 0.39)$, for the dissociation between cardiac and vascular systems (profile 2) h^2 is 0.81 and for the covariation between cardiovascular and GSL systems (profile 3) h^2 is 0.82. These results confirm hypothesis 1.

4.5. Analysis of hypothesis 2

Multivariate QGA is not an option for analysing these data, because a sample of only 100 twin pairs is to insufficient to detect differential heritabilities. For this reason, we used a method developed by Eaves and Eysenck (1976) (Eaves and Young, 1981) for the computation of the genetics of interactions. The crux of this method is that the expectations of the Means Squares from an ANOVA analysis are reparametrised into variance and covariance components in terms of the simple genetic AE-model. These (co)variances are used to compute the genetic and environmental parameters for main effects of the person (P), and the parameters for the interaction ($P \times S$). From these parameters we can estimate the value of the heritability coeffiecient as:

$$h^2 = 1/2G/(1/2G + E)$$

(Eaves and Eysenck, 1976; Ozer, 1986; McGraw and Wong, 1996).

To obtain the necessary Mean Squares, data were analysed for both zygosity groups, with response profiles as dependent variables and twin pair (T), twin halve (t), situation ($S =$ film) and response ($I =$ different 30 s scenes in a film) as independent variables. Although 't' is sometimes defined as nested within T, an all variables crossed approach is chosen, because twin 1 and twin 2 are interchangeable, as demonstrated by Eaves and Eysenck, (1976).

4.6. Results

An ANOVA on twin pairs × twin halves × situations × scenes ($N \times 2 \times 8 \times 2$) is done in BMDP-V8 (Dixon, 1988).

Table 2
Model fitting results for physiological variables

Physiology	IBI	SBP	DBP	GSL	Profile 1	Profile 2	Profile3
r_{MZ}	0.54	0.44	0.27	0.12	0.65	0.79	0.81
r_{DZ}	0.32	0.27	0.23	0.07	0.08	0.2	0.37
χ^2	4.455	3.316	2.647	1.079	3.465	3.368	2.342
df	4	4	4	4	3	4	4
P	0.348	0.506	0.618	0.898	0.325	0.498	0.676
$\Delta\chi^2$	0.29	0.012	0.949	0	4.425	0.498	0.108
Estimates							
h^2	0.41	0.42	0.32	0.38	0.4	0.81	0.82
d^2					0.39		
e^2	0.59	0.58	0.68	0.62	0.21	0.19	0.18

Abbreviations: $\Delta\chi^2$: df and P-value testing for the best fitting model. $\Delta\chi^2$ is the difference between the full and restricted model, with 1 df. When $\Delta\chi^2 > 3.84$ the ADE model has the best fit. The parameter estimates for additive heritability (h^2), dominance heritability (d^2), and environmentality (e^2) are given. IBI, interbeat interval; SBP, systolic blood pressure; DBP, diastolic bloodpressure; GSL, galvanic skin level.

Table 3
Mean squares of analysis of variance in BMDP-V8, for physiological response profiles

Source	df		Profile 1		Profile 2		Profile 3	
	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ
Film (S)	7	7	4.334	4.506	8.368	5.198	4.135	2.582
Twin pairs (P)	55	36	8.732	7.352	3.817	1.809	3.22	3.037
Twin halves (t)	56	37	4.152	3.791	1.625	2.159	1.652	1.788
Scene (I)	1	1	1.264	0.035	0.343	0.812	0.085	0.169
$S \times P$	385	252	1.001	0.879	0.585	0.506	0.523	0.261
$S \times t$	392	259	0.672	0.836	0.425	0.459	0.432	0.251
$S \times I$	7	7	1.517	0.766	0.282	0.121	1.252	0.275
$P \times I$	55	36	0.284	0.106	0.084	0.073	0.102	0.03
$I \times t$	56	37	0.245	0.142	0.094	0.068	0.128	0.04
$S \times I \times P$	385	252	0.285	0.145	0.09	0.072	0.184	0.05
$S \times I \times t$	392	259	0.227	0.121	0.086	0.075	0.193	0.05
PI pooled	184		0.209		0.095		0.091	
SPI pooled	1288		0.201		0.081		0.013	

Abbreviations: Profile 1, dissociation between cardiovacular and GLS systems; Profile 2, dissociation between cardiac and vascular systems; Profile 3, Covariation between cardiovascular and GSL systems.

Table 3 presents the results of the ANOVA in BMDP-V8, for response profiles. Table 4 displays the genetic and environmental parameters, and the heritability coefficients for response profiles, for the main and interaction effects.

Hypothesis 2 is confirmed by the data. The idiosyncratic interaction between an individual's specific response potential and the properties of the situation to elicit autonomic responses is partly an inherited mechanism, and therefore a trait in it's own right.

5. Discussion and conclusions

Hypothesis 1 is confirmed by our data. Although we could find no genetic research on physiological response profiles, an attribution of 79–82% of the total

Table 4
Estimates of genetic and environmental components, for physiological response profiles

Parameter	Profile 1	Profile 2	Profile 3
G_p	0.572	0.212	0.106
E_p	0.183	0.073	0.071
$G_{p \times s}$	0.148	0.015	0.075
$E_{p \times s}$	0.252	0.141	0.166
h^2P	0.61	0.59	0.43
$h^2P \times S$	0.23	0.05	0.19

Abbreviations: G, genetic parameter; E, environmental parameter.

variance of a trait in the population to genetic effects is uncommonly large (Plomin et al., 1990). It is possible that these large differences in heritability coefficients between response profile scores and single variables are the results of a higher reliability of the response profiles measurement. After all, reliability has a tendency to increase when more items of the same concept are taken into account (Murphy and Davidshofer, 1991). It is also possible that the extern validity of our measures has been enhanced as a result of using an ecologically valid situational measure to induce stress reactions, rather than laboratory stress inducers (cold pressure test, Stroop's colour word inference test). Higher extern validity tends to increase the reliability of the data, as lower validity results in attenuation and lower reliability (Cronbach, 1951). However, computation of Cronbach's alpha for single variables and response profiles revealed no differences large enough to explain the differences in heritability between both groups of variables. For the single variables, Cronbach's alpha varied between 0.80 and 0.93 (IBI 0.93, GSL 0.80) and for the response profiles between 0.80 and 0.87 (response profile 1:0.8, response profile 2:0.87 and response profile 3:0.86).

Our results support the view that response profiles deserve study, to be strongly recommended along with the study of single variables. Functional combinations of autonomic measures are reliable personality traits in their own right, stable over time and modes of measurement (Hettema et al., 2000), and highly inheritable. Up to 80% of the variance in the population for the response profiles can be explained by differences in individual genotypes.

Hettema et al., (2000) make use of these response profiles when defining a model for information processing. As their point of departure they used the model of Pribram and McGuinness, (1975, 1992). Pribram and McGuinness defined three information processing systems; Familiarisation, Effort, and Readiness. Familiarisation being associated with familiarising changing inputs, Readiness is associated with output regulation, and Effort has a function in coordinating Familiarisation and Readiness systems, being associated with 'throughput'. The response profile that is associated with a dissociation between the cardiovascular reactivity and galvanic skin level measures is connected with 'Familiarisation'. The response profile that shows a dissociation between heart rate reactivity and blood pressure changes is associated with throughput processes and connected with Pribram and McGuinnes construct of 'Effort'. The response profile based on the covariation of heart rate reactivity, blood pressure changes, and galvanic skin level, is related to output processes and connected to 'Readiness'. Hettema et al., (2000) sum up the evidence supporting this interpretation. After the identification of the dimensions with the aid of multivariate techniques they conducted three follow-up validation studies to demonstrate the fit between the response profiles and the information-processing dimensions of Pribram and McGuiness.

Hypothesis two is also confirmed by our data. The interaction between a person and the topic situation is not only a statistical concept, but an heritable feature of the person. Our data indicate genetic influences on the main effect on P, and on the $P \times S$-interaction effects. Concerning the relation between genetic influences and the demands of the topic situation, recent evidence of behavioural genetic studies

have raised important questions about the relationship between genes and environment (Barinaga, 1994). The evidence grows that genes not only exert their influence directly, but also indirectly through gene-environment interactions and correlations (McVicker-Hunt, 1981; Scarr and McCartney, 1983). The results of this study suport this view. There are at least two ways genes influence the way people physiologically respond to a situation: directly, by making people more genetically liable to express a certain trait, and indirectly by influencing the idiosyncratic interaction between a person and his environment. Our results yielded strong support for a genetic basis for individual differences in situation specific responding for all three response profiles.

In future research it would be recommendable to use a sample that has both male and female subjects. Although most research is conducted with male only groups (Turner and Hewitt, 1992), it is not recommended to use only female twin samples for further research, because the possibility of generalisation of the results over both sexes can not be guaranteed.

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