

## GENETIC AND ENVIRONMENTAL INFLUENCES ON TEMPERAMENT IN ADOLESCENCE

*Sergei B. Malykh,  
Elena D. Gindina,*

*Viktoria V. Nadyseva*

*Psychological Institute of the Russian Academy of Education  
Moscow*

This study, which is a part of a Moscow longitudinal twin project, aims to explore genetic and environmental contributions to inter-individual variability of temperamental traits in adolescence on the basis of a Russian sample. 85 monozygotic (MZ) and 64 same-sex dizygotic (DZ) twin pairs aged 12 – 14 years completed the children version of Rusalov Structure of Temperament Questionnaire (C-STQ). The results of model-fitting analyses indicate considerable hereditary determination of individual differences in 3 out of the 8 C-STQ dimensions - social tempo, object-related emotional sensitivity, and social emotional sensitivity. Non-shared environmental effects explained the rest of the total variance in these dimensions. Individual differences in the other STQ dimensions were due to environmental factors.

**Keywords:** monozygotic twins, dizygotic twins, adolescents, individual differences, temperament, genotype, environment

Despite their age-old history, the studies of temperament are still attracting many researchers' close attention. And this is no accident, considering its contribution to the understanding of human behavior. Despite certain distinctions in theoretical approaches, most researchers define temperament as biologically determined traits that manifest themselves in early childhood and retain the ontogenetic and cross-situational stability of individual behavioral style (Buss, and Plomin, 1975; Cloninger, 1987; Eysenck, 1981; Gray, 1982; Krupnov, 1992; Nebylitsin, 1976; Rothbart, and Derryberry, 1981; Rusalov, 1979; Teplov, 1985; Zuckerman, 1994 etc.). One of the principal criteria used to regard a certain trait as a temperamental feature is, in the view of many research-

---

This study was supported by HIII-5774.2008.6 grant from The Federal Agency for Science and Innovation of the Russian Federation.

ers (A. Buss, R. Plomin, J. Strelau, V.M. Rusalov, et al.), its hereditary determination.

There already exists a large enough body of empirical data on hereditary determination of individual human traits viewed as temperament (Babynin, 2003). Most studies address the heritability of the “Big Three” (extraversion, neuroticism, and psychoticism) and “Big Five” (openness to experience, awareness, extraversion, agreeableness and neuroticism) personality traits (Eysenck, 1981; John, 1990; Norman, 1963, etc.). It should be noted that despite the fact that American and European psychology uses the concept of personality to define these traits, their main specifics give reason to regard them as belonging to the sphere of temperament (Strelau, and Angleitner, 1991; Strelau, Angleitner, Bantelmann, and Ruch, 1990, etc.).

The findings of twin studies point to a moderate contribution of hereditary factors to the variability of these characteristics: approximately 30 – 60% of variance can be explained by genetic factors, while the remaining variance is due to such factors as family environment, the nonsystematic measurement error, and the systematic error of method (Eaves, et al., 1989, Floderus, Myrhed, et al., 1980; Henderson, 1982; Loehlin, 1992; Loehlin, and Nichols, 1976; Plomin, Chipuer, and Loehlin, 1990; Rose, et al., 1988; Viken, et al., 1994, etc). For a number of characteristics, both an influence of nonadditive factors (e.g., extraversion – Eaves, et al., 1989, etc.) and the presence of sex differences (neuroticism – Eaves, et al., 1989; Finkel, and McGue, 1997; Loehlin, 1992; Viken, et al., 1994, etc.) were discovered.

Despite some discrepancies, the findings of twin studies are consistent and stable enough even if different methods are used to diagnose the “Big Five”: the subjects’ self-ratings (Loehlin, 1992; Plomin, Chipuer, and Loehlin, 1990; Rose, 1995); expert ratings (those of people who have a good knowledge of their subjects Riemann, Angleitner, and Strelau, 1997); the twins’ ratings of one another (Neale, et al., 1992); or expert ratings of video recordings of the subjects’ behavior (Borkenau, et al., 2001).

The findings of the studies performed within the framework of other theoretical temperament models (Cloninger, 1987; Kohnstamm, Bates, and Rothbart, 1989; Zuckerman, 1994) also testify to the contribution of the genotype to the variance of temperamental features. The influence of hereditary factors was demonstrated in the variance of four

temperament dimensions (novelty seeking, harm avoidance, reward dependence, and persistence) identified in C. Cloninger’s psychobiological model (Stalling, et al., 1996). What is more, studies of the molecular-genetic foundations of temperament have shown that the polymorphism of the gene which codes the dopamine receptor (DRD4) is connected with “novelty seeking” dimension. It turned out that the subjects possessing longer DRD4 allele forms had higher scores for novelty seeking (Benjamin, Ebstein, Belmaker, 2002).

Similar results were obtained for the “sensation seeking” scale (Zuckerman, 1994). Two major twin studies yielded high enough (60%) estimates of heritability for general “sensation seeking” (Fulker, Eysenck, and Zuckerman, 1980; Koopmans, et al., 1995). The existence of the contribution of the genotype to the variance of this trait is also indicated by the findings ( $r = 0.54$ ) of a study on separated monozygotic twins (Tellegen, et al., 1988).

Most genetic studies of temperament in childhood used infants and children in early ages. As a rule, the diagnosis of temperament in these studies is based on the parental ratings of a child’s temperament (Buss, and Plomin, 1984; Gjone, and Stevenson, 1997; Goldsmith, and Campos, 1982; 1986; Goldsmith, Buss, and Lemery, 1997; Matheny, and Dolan, 1980; Plomin, et al., 1993; Spinath, and Angleitner, 1998; Stroganova et al., 2000; Torgersen, 1987; 1989; Wilson, and Matheny, 1986, etc.). The heritability of temperamental traits in the studies vary from 20% to 50% (DiLalla, and Jones, 2000); notable are the extremely low DZ twins correlations, which may be explained by contrast effects, assimilation effects, and nonadditive genetic variance (Saudino, et al., 1995; Spinath, Angleitner, 1998). The influence of hereditary factors also manifests itself when expert ratings are used (Braungardt, et al., 1992; Cherny, et al., 1994; DiLalla, and Jones, 2000; Emde, et al., 1992; Matheny, 1980, 1983, 1989; Plomin, et al., 1993; Saudino, and Eaton, 1991; Saudino, Plomin, and DeFries, 1996, etc.). While in the first weeks of life genetic influences on temperament are absent (Riese, 1990), by the end of the second half of the first year significant estimates of genetic influence are obtained (Goldsmith, and Campos, 1982; 1986; Saudino, Plomin, and DeFries, 1996; Wilson, and Matheny, 1986, etc.).

Despite the large number of works, behavior genetic studies of temperament in adolescence are all but nonexistent. In the meantime, such works are especially important in the study of adolescents (1992) be-

cause this age is the time of important hormonal shifts and biological growth accompanied by major physical change. What is more, it is in adolescence that a capacity for reflection is formed; for this reason, parental ratings can be complemented by the adolescents' reports of their experience which parents may not be in a position to observe.

In the few studies that involved adolescents (Eaves, et al., 1989; Macaskill, 1994; Saudino, et al., 1995), the samples usually comprised subjects whose ages varied within a broad enough range. In the American study (Saudino, et al., 1995), the subjects' age varied from 10 to 18 ( $M = 13.7$ ); in the British study (Eaves, et al., 1989), from 7 to 17, and in the Australian study (Macaskill, 1994), from 11 to 18 inclusive. At the same time, the studies show that the indicators of heritability of temperamental features can change depending on age (Torgersen, 1987; 1989; Saudino, et al., 2001; Gagne, et al. 2003, etc.). Such changes can also occur throughout adolescence. Of interest in this context is analysis of data in narrower age brackets and further interpretation of the obtained findings with account of the psychological and physiological characteristics of different periods of puberty.

Thus, the purpose of this study was to analyze the influence of genetic and environmental factors in inter-individual variance of temperament in adolescence (on the basis of a Russian sample).

## Method

### Subjects

The study involved 85 pairs of MZ twins (49 pairs of boys and 36 pairs of girls) and 64 pairs of DZ twins (33 pairs of boys and 31 pairs of girls) aged 12 - 14 ( $M = 13.28$ ;  $SD = 0.61$ ). The sample included twins who take part in the Moscow Longitudinal Twin Study<sup>1</sup>. The twins' zygosity was determined using the method of polysymptomatic similarity (Cohen, et al., 1973); the pairs with an uncertain diagnosis were not included in the study.

<sup>1</sup> The project "Moscow Longitudinal Twin Study" was supported by ZZ5000/426 and KWD100 grants from International Scientific Foundation (head - Malykh S.B.), by 94-06-19755, 99-06-80161, 01-06-80134 grants from Russian Basic Research Foundation (head - Malykh S.B.), by 96-03-042446, 98-06-08084 grants from Russian Humanitarian Research Foundation (head - Malykh S.B.), and by the direction 03 from RF Ministry for Industry, Science, and Technology ("The Health Status of the Russian Population", head - Malykh S.B.).

### Methodology

To assess temperamental traits, we used the child version of Rusalov's Structure of Temperament Questionnaire (C-STQ; Rusalov, 1992) designed to diagnose temperament in the children aged 13 - 17. The questionnaire contains 105 questions which require "yes" or "no" for an answer and which makes it possible to obtain values for eight temperament scales: object-related ergonicity (ER), social ergonicity (SER), object-related plasticity (P), social plasticity (SP), object-related tempo (T), social tempo (ST), object-related emotional sensitivity (EM), and social emotional sensitivity (SEM). Each scale contains 12 questions of varying degrees of complexity scoring from 0 to 12 points. The questionnaire also has a control scale (C), which determines the degree of social desirability.

### Genetic analysis

The twins' intra-pair similarity was assessed through Fisher's intra-class correlation coefficients (Fisher, 1918).

To test the hypothesis on the structure of phenotypic variance of temperament, we used the confirmatory factor analysis apparatus (Bollen, 1989; Loehlin, 1987). The factor model parameters were determined using the maximum-likelihood technique.

As is known, confirmatory factor analysis implies that the relationship between the observed parameters and the examined non-observed (latent) characteristics is described by the linear model

$$x = \Lambda f + \varepsilon$$

where  $x$  is the vector of the observed variables,  $f$  is the vector of the latent variables (factors),  $\Lambda$  is the factor load matrix, and  $\varepsilon$  is the vector of random perturbations.

The observed variables  $P_i$  were constituted by deviations from average assessments on the C-STQ scale, and latent variables  $A_p$ ,  $D_p$ ,  $C_i$  and  $E_i$  by values determined by additive genetic, nonadditive genetic (domination and epistasis) factors, as well as by the influences of shared and nonshared environment.

The structure of phenotypic variance  $P_i$  can be presented as a sum of contributions of the additive genetic component, nonadditive genetic component, common environment component, and the individual environment component:

$$Var(P_i) = a^2 + d^2 + c^2 + e^2.$$

Value  $a^2$  determines the contribution of additive genetic influences,  $d^2$  – of nonadditive genetic influences, and  $c^2$  и  $e^2$  – the influence of common and individual environment respectively. Additive genetic correlations for mono- and dizygotic twins are equal to 1 and 0.5 respectively; nonadditive ones, to 1 and 0.25; and common environment ones, to 1 for both types of twins; individual environment for different twins does not correlate by definition.

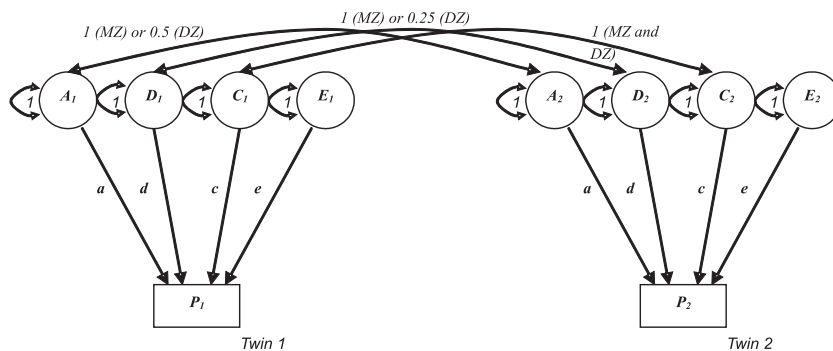
This model can be conveniently presented graphically as a diagram of path coefficients, where (see Fig. 1):

- the observed variables are designated by rectangles;
- the latent variables are designated by circles;
- the arrows (or routes) pointing the same way present the cause-and-effect links between variables;
- the arrows pointing in two directions present the covariance links between variables (specifically, they also present dispersion).

In the process of solution, we determined path coefficients  $a$ ,  $d$ ,  $c$  and  $e$ . They were assessed using the maximum likelihood technique, which is equivalent to optimization problem with the following fitting function to be minimized

$$F = [\ln |\Sigma| - \ln |S| + \text{tr}(S\Sigma^{-1}) - p] (N-1),$$

where  $S$  – observed covariance matrix,  $\Sigma$  – expected covariance matrix expressed via observed parameters to be estimated,  $|\Sigma|$  and  $|S|$  – deter-



**Figure 1.** Univariate model for data from monozygotic (MZ) or dizygotic (DZ) twins

minants of matrices  $\Sigma$  and  $S$ ,  $\text{tr}(S\Sigma^{-1})$  – trace of matrices  $(S\Sigma^{-1})$ ,  $N$  – sample size used for calculation of matrix  $S$ ,  $p$  – order of matrix  $S$ .

In our case,  $\Sigma = \Lambda \Phi \Lambda'$ , where  $\Phi$  is the latent variables covariance matrix. Through the path coefficients, matrix  $\Sigma$  is expressed in the following way:

$$\begin{pmatrix} a^2 + d^2 + c^2 + e^2 & xa^2 + yd^2 + c^2 \\ xa^2 + yd^2 + c^2 & a^2 + d^2 + c^2 + e^2 \end{pmatrix}$$

where for monozygotic twins  $x = y = 1$ , and for dizygotic,  $x = 0,5$ ,  $y = 0,25$ .

In order for the parameters to be identified, their number must not exceed the number of available statistics. In our case, the number of such statistics is  $p(p+1)/2$ , the number of differing elements in symmetrical matrix  $S$ . The number of degrees of freedom ( $df$ ) is determined as the difference between the number of statistics and the number of estimated parameters.

To obtain a sufficient number of statistics, the temperamental characteristics were assessed simultaneously for the MZ and DZ twin pairs (each type of twins was matched by matrix  $\Sigma$  of its own). The sum of corresponding functions  $F_{MZ}$  and  $F_{DZ}$  for MZ and DZ pairs was used as a criterion to be minimized.

Minimum of this function, which results from optimization problem solution, shows whether the model fits the observed data. Large values correspond to bad fit and small values – to good fit. Under certain conditions (Bollen, 1989), this goodness-of-fit measure is distributed as a chi-square ( $\chi^2$ ) distribution. That is why  $\chi^2$ -statistic is used to clarify whether the fit is adequate or not. The same statistic makes it possible to compare alternative models, thus a goodness-of-fit measure for the full model may be compared with the corresponding characteristics of reduced models, in which some of the estimated parameters are taken as equal to zero. Since the difference in the values of  $\chi^2$ -statistics for the full and the reduced models is itself distributed as  $\chi^2$ , it may be used to ascertain whether the parameters dropped from the model are significant or not (Loehlin, 1987).

To assess the fit of the model to the results of the measurements, the ( $\chi^2$ ) criterion was used. The same criterion also made it possible to compare alternative models and examine the statistical significance of the parameters excluded from the model. Along with criterion  $\chi^2$ , the

quality of the models was assessed through the information criterion *AIC* (*Akaike's Information Criterion*), which reflects the degree of the model's parsimony and is calculated from formula

$$AIC = \chi^2 - 2df,$$

where  $\chi^2$  is the chi-square statistics, and *df* is the number of degrees of freedom. The *ACI* criterion gives preference to the models which fit the results of measurements and have a smaller number of parameters. Larger negative values (taken absolutely) of this criterion represent better fitting models (Neale and Cardon, 1992).

For all C-STQ parameters, the following models were tested in the same sequence:

I. The model reflecting the null hypothesis ( $H_0$ ). Under this model, the differences observed between two groups of twins can be explained by random factors or sampling error. In this case, the number of degrees of freedom is equal to three (two groups of twins, three correlation coefficients for each group, the model implies identity of these correlations for the two groups, that is, three parameters are assessed;  $6 - 3 = 3$ ).

II. The full model (ADCE). The model includes all four variance components: the additive and nonadditive genetic components, and the common and individual environmental components. This model was compared with five reduced models described below: this made it possible to test the significance of the various variance components which did not figure in the reduced models.

III. The genotype-environmental model (ACE). This model includes both additive genetic and family environment components. When this model fit the data better than the simple genetic and environment models, one may assume that the variance of the examined parameter is affected by both additive genetic and environmental factors. For this model to be adopted, all assessed parameters must differ significantly from zero.

IV. The additive-dominant model (ADE). This model implies that intra-pair similarity is determined by the genetic component of variance, while the environment influences explain only the intra-pair differences. The model allows that the genetic component of variance includes both an additive and a nonadditive component.

V. The dominant-environmental model (DCE). The model includes both nonadditive genetic and family environment components. In the

cases when this model fit the data better than the genetic and environmental models, one may assume that the variance of the examined trait is influenced by both nonadditive genetic and environmental factors. For this model to be adopted, the assessed parameters must differ significantly from zero.

VI. The simple genetic model (AE). This model implies that the environment does not influence similarity for the observed characteristic, and the genetic component of variance is exhausted by the additive component. If this model does not fit the data, one may assume that the similarity for the given trait is influenced by such factors as common family environment, dominance, associative selection, etc. A comparison of this model with the ADE and ACE models reveals the presence of a contribution of the nonadditive and the environmental component of variance to similarity for the examined trait.

VII. The environmental model (CE). This model implies that the intra-pair similarity for the examined trait is totally determined by the environmental component. Non-fit of the model to the data suggests the presence of the genetic component in variance. This model helps identify those characteristics which are determined by strictly environmental factors and do not depend on genetic variance.

## Results

*The psychometric characteristic of the questionnaire.* The internal consistency of C-STQ scales were assessed by Cronbach's alpha reliability coefficient (Cronbach, 1951). Cronbach's alpha coefficients across scales ranged from 0.67 to 0.89 with a mean of 0.78. The obtained results are similar to the questionnaire standardization data (Rusalov, 1992) and testify to the reliability of the obtained data as regards the inner consistency of the scales of the questionnaire.

*Descriptive statistics.* There were significant mean differences on some scales of the questionnaire. Analysis of gender differences in the C-STQ scales showed that girls had a significantly lower means for scales ER ( $t(147) = 2.232, p < 0.027$ ), SP ( $t(147) = 2.712, p < 0.007$ ), and ST ( $t(147) = 2.168, p < 0.032$ ), and higher mean for scale SEM ( $t(117.583) = -2.078, p < 0.040$ ). The means in the groups of MZ and DZ twins differed only for scale EM: DZ twins had higher means for scale EM ( $t(147) = -2.107, p < 0.037$ ). Since the sample consis-



ted of twins of approximately the same age, age differences were not analyzed.

To check the assumptions on the equality of variances in the MZ and DZ twin samples, a two-sample F-test was used. No significant differences in the size of variances were discovered. This means that the obtained data do not contradict the basic assumption of the twin method on the equality of variances in the MZ and DZ twins.

*Intra-pair similarity.* The intra-pair correlations in the MZ twin group vary from 0.380 ( $p < 0.01$ , P scale) to 0.673 ( $p < 0.01$ , EM scale) yielding a mean similarity coefficient of 0.55 across scales. The intra-pair correlations of DZ twins are somewhat lower, lying between 0.271 ( $p < 0.05$ , EM scale) and 0.546 ( $p < 0.01$ , SP scale); the mean across scales is 0.41. MZ twin correlations significantly exceed the DZ twins' on the ST scale and on both emotional sensitivity scales; for the ST and EM scales, intra-pair correlations in the MZ twin group more than double the correlations in the DZ twin group. These findings indicate that individual differences for ST, EM, and SEM scales are at least in part explained by the influence of genetic factors.

*Structural modeling (model fitting).* The first model to be tested for all C-STQ scales was the model that reflects the null hypothesis. The null model fit well the data for parameters ER ( $\chi^2_{(3)} = 0.31$ ;  $p = 0.96$ ), SER ( $\chi^2_{(3)} = 0.21$ ;  $p = 0.98$ ), P ( $\chi^2_{(3)} = 0.22$ ;  $p = 0.97$ ), SP ( $\chi^2_{(3)} = 0.42$ ;  $p = 0.94$ ), T ( $\chi^2_{(3)} = 0.86$ ;  $p = 0.83$ ), and C ( $\chi^2_{(3)} = 0.121$ ;  $p = 0.75$ ). Thus, the differences between the MZ and DZ twin groups obtained for these parameters can be explained by a systematic error of method or nonsystematic influences. For parameters ST ( $\chi^2_{(3)} = 8.78$ ;  $p = 0.03$ ), EM ( $\chi^2_{(3)} = 11.50$ ;  $p = 0.01$ ), and SEM ( $\chi^2_{(3)} = 9.39$ ;  $p = 0.02$ ), the model that reflects the null hypothesis and implies that the covariances obtained for the two twin groups reflect random results and are not connected with latent variables, does not fit the data.

The next to be tested was a full model including all four variance components: the additive and nonadditive genetic components, and the components of common and individual environment. This model is also fit well the data for parameters ER ( $\chi^2_{(2)} = 1.93$ ;  $p = 0.38$ ), SER ( $\chi^2_{(2)} = 0.17$ ;  $p = 0.92$ ), P ( $\chi^2_{(2)} = 0.93$ ;  $p = 0.63$ ), SP ( $\chi^2_{(2)} = 0.46$ ;  $p = 0.79$ ), T ( $\chi^2_{(2)} = 0.45$ ;  $p = 0.80$ ), and C ( $\chi^2_{(2)} = 1.34$ ;  $p = 0.51$ ); however, the fit and model simplicity indicators (for AIC) are somewhat inferior to those of the null model. For parameters ST ( $\chi^2_{(2)} = 0.40$ ;  $p = 0.82$ ), EM

( $\chi^2_{(2)} = 0.02$ ;  $p = 0.99$ ), and SEM ( $\chi^2_{(2)} = 3.96$ ;  $p = 0.14$ ), the full model fit the data significantly better than the null model.

The model selection logic is the search for a model that would, on the one hand, provide the best fit to the data and, on the other, would include the fewest components (that is, the simplest model with the highest number of degrees of freedom). In the process of exclusion of parameters from the full model, the significance of individual variance components is tested.

Model III (ACE), which tests the significance of the nonadditive component, offers a minor improvement of the degree of fit but somewhat raises the degree of the model's simplicity (for AIC) for ST ( $\Delta\chi^2_{(1)} = 0.190$ ;  $p = 0.66$ ;  $ACI = -5.41$ ) and EM ( $\Delta\chi^2_{(1)} = 0.190$ ;  $p = 0.83$ ;  $ACI = -5.91$ ). For the other C-STQ scales, the exclusion of this component from the model does not change the degree of fit but increases the models' simplicity.

Testing the need to retain the common environmental parameter in the model (Model IV(ADE)) demonstrated that the exclusion of this parameter from the model significantly lowers the degree of the model's fit to the observed covariance matrices for parameters ER ( $\Delta\chi^2_{(1)} = 4.271$ ;  $p = 0.04$ ;  $ACI = 0.20$ ), SER ( $\Delta\chi^2_{(1)} = 3.530$ ;  $p = 0.06$ ;  $ACI = -2.30$ ), SP ( $\Delta\chi^2_{(1)} = 6.697$ ;  $p = 0.01$ ;  $ACI = 1.16$ ) and T ( $\Delta\chi^2_{(1)} = 3.182$ ;  $p = 0.07$ ;  $ACI = -2.37$ ). There is also a worsening of the indicators of the degree of model simplicity. For parameters P ( $\Delta\chi^2_{(1)} = 1.200$ ;  $p = 0.27$ ;  $ACI = -3.87$ ), ST ( $\Delta\chi^2_{(1)} = 0.190$ ;  $p = 0.66$ ;  $ACI = -5.41$ ), EM ( $\Delta\chi^2_{(1)} = 0.000$ ;  $p = 1.00$ ;  $ACI = -5.98$ ), SEM ( $\Delta\chi^2_{(1)} = 0.379$ ;  $p = 0.54$ ;  $ACI = -1.66$ ), and the Control scale ( $\Delta\chi^2_{(1)} = 0.641$ ;  $p = 0.42$ ;  $ACI = -4.01$ ), the additive-dominant model insignificantly lowers the degree of fit as compared to the original Model II (ACDE), and is more parsimonious; this provides an opportunity to exclude the common environment parameter from variance.

For all C-STQ scales, reduction of the full model by excluding the additive component (Model V (DCE)) does not change the degree of the model's fit to the data but improves the AIC criterion, which reflects the model's simplicity. Thus, when comparing this model with Model II, value  $\chi^2$  is equal to zero and is statistically insignificant for all C-STQ scales ( $\chi^2 = 0.000$ ;  $p = 1.000$ ). The additive genetic component of variance can, therefore, be excluded.

Further reduction of the full model by excluding the nonadditive genetic component and the common environmental component

(Model VI(AE)) significantly worsens the degree of fit and model simplicity for scale SP (when comparing the simple genetic model with model II (ACDE), value  $\chi^2$  is statistically significant:  $\Delta\chi^2_{(2)} = 6.697$ ;  $p = 0.04$ ;  $ACI = -0.84$ ), as is for the ER scale ( $\Delta\chi^2_{(2)} = 4.271$ ;  $p = 0.12$ ;  $ACI = -1.80$ ). For scales SER ( $\Delta\chi^2_{(2)} = 3.530$ ;  $p = 0.17$ ;  $ACI = -4.30$ ) and T ( $\Delta\chi^2_{(2)} = 3.182$ ;  $p = 0.20$ ;  $ACI = -4.37$ ), the degree of fit also goes down, while the indicator of the model's simplicity insignificantly improves. For scales P ( $\Delta\chi^2_{(2)} = 1.200$ ;  $p = 0.55$ ;  $ACI = -5.87$ ), ST ( $\Delta\chi^2_{(2)} = 0.190$ ;  $p = 0.91$ ;  $ACI = -7.41$ ), EM ( $\Delta\chi^2_{(2)} = 0.155$ ;  $p = 0.93$ ;  $ACI = -7.83$ ), SEM ( $\Delta\chi^2_{(2)} = 0.379$ ;  $p = 0.83$ ;  $ACI = -3.66$ ), and C ( $\Delta\chi^2_{(2)} = 0.641$ ;  $p = 0.73$ ;  $ACI = -6.01$ ), the degree of fit becomes insignificantly lower, although the degree of the model's simplicity increases significantly.

And, finally, the exclusion of the genetic components from the full model (environmental model – Model VII) does not significantly lower the degree of fit for scales ER ( $\Delta\chi^2_{(2)} = 0.041$ ;  $p = 0.98$ ), SER ( $\Delta\chi^2_{(2)} = 0.0531$ ;  $p = 0.97$ ), P ( $\Delta\chi^2_{(2)} = 0.191$ ;  $p = 0.91$ ), SP ( $\Delta\chi^2_{(2)} = 0.000$ ;  $p = 1.00$ ), T ( $\Delta\chi^2_{(2)} = 0.542$ ;  $p = 0.76$ ), and C ( $\Delta\chi^2_{(2)} = 0.162$ ;  $p = 0.92$ ), and improves the model's simplicity. The environmental model fit the data well enough (as compared to the other models) for ER ( $\chi^2_{(4)} = 1.97$ ;  $p = 0.74$ ;  $ACI = -6.03$ ), SER ( $\chi^2_{(4)} = 0.23$ ;  $p = 0.99$ ;  $ACI = -7.77$ ), P ( $\chi^2_{(4)} = 1.12$ ;  $p = 0.89$ ;  $ACI = -6.88$ ), SP ( $\chi^2_{(4)} = 0.46$ ;  $p = 0.98$ ;  $ACI = -7.54$ ), T ( $\chi^2_{(4)} = 0.99$ ;  $p = 0.91$ ;  $ACI = -7.01$ ), and C ( $\chi^2_{(2)} = 1.51$ ;  $p = 0.83$ ;  $ACI = -6.49$ ). The exclusion of the genetic components from the model lowers the degree of fit and the Akaike criterion for scales ST, EM, and SEM. It is obvious that similarity for these scales is influenced by genetic factors, since the environmental model does not fit the data for ST ( $\chi^2_{(4)} = 9.00$ ;  $p = 0.06$ ;  $ACI = 1.00$ ), EM ( $\chi^2_{(4)} = 11.50$ ;  $p = 0.02$ ;  $ACI = 3.50$ ), and SEM ( $\chi^2_{(4)} = 10.09$ ;  $p = 0.04$ ;  $ACI = 2.09$ ); value  $\chi^2$ , obtained when this model is compared to Model II, is statistically significant for ST ( $\Delta\chi^2_{(2)} = 8.598$ ;  $p = 0.01$ ), EM ( $\Delta\chi^2_{(2)} = 11.480$ ;  $p = 0.00$ ), and SEM ( $\Delta\chi^2_{(2)} = 6.132$ ;  $p = 0.05$ ).

It is easy to see that among the models that test the significance of variance components, the best fit to the data for ER, SER, P, SP, T, and C is provided by Model VII (the environmental model). Although for scale T, value  $p$  is somewhat higher for the genotype-environmental and the dominant-environmental models, Model VII includes more degrees of freedom (four, as against three), and can be accepted as providing the best fit to the data on the basis of the simplicity criterion. The data for

Table 1

**Estimates of the components and percentage of explained variance for the best fitting structural model**

Scale	Model	$\chi^2$	df	$p$	$a^2$		$c^2$		$e^2$	
					Estimate of variance component	Percentage of explained variance	Estimate of variance component	Percentage of explained variance	Estimate of variance component	Percentage of explained variance
Object-related ergonicity	CE	1.97	4	0.74	–	–	2.047	49	2.088	51
Social ergonicity	CE	0.23	4	0.99	–	–	2.187	46	2.348	54
Object-related plasticity	CE	1.12	4	0.89	–	–	1.756	36	2.352	64
Social plasticity	CE	0.46	4	0.98	–	–	2.092	55	1.877	45
Object-related tempo	CE	0.99	4	0.91	–	–	2.591	51	2.564	49
Social tempo	AE	0.59	4	0.96	2.552	60	–	–	2.086	40
Object-related emotional sensitivity	AE	0.17	4	1.00	3.098	66	–	–	2.220	34
Social emotional sensitivity	AE	4.34	4	0.36	2.819	66	–	–	2.046	34
Control scale	CE	1.51	4	0.83	–	–	1.153	32	1.699	68

*Note:* Descriptions of the models are provided in the method section;  $a^2$  — the additive genetic component of phenotypic variance;  $c^2$  and  $e^2$  respectively — common and individual environment components; the empty spaces in the Table mean that the parameter is absent in the model.

scales ST, EM, and SEM are best fitted by Model VI (the simple genetic model), which includes the additive genetic component and the individual environment component.

Table 1 presents estimates of variance components and the structure of phenotypic variance (in %) for the C-STQ scales. It is easy to see that the data for scales ER, SER, P, SP, T, and C are described by a simple environmental model, which includes the common and individual environment components. Common environment significantly influences parameters E ( $c^2 = 49\%$ ), SER ( $c^2 = 46\%$ ), P ( $c^2 = 36\%$ ), SP ( $c^2 = 55\%$ ), and T ( $c^2 = 51\%$ ), and the control scale ( $c^2 = 32\%$ ). The influences of individual environment explain the remaining 51%, 54%, 64%, 45%, 49%, and 68% respectively. The best fit to the data for scales ST, EM, and SEM is provided by the simple genetic model, within which the additive genetic influence proves less pronounced in the case of individual differences for ST ( $a^2 = 60\%$ ) as compared with the individual differences for scales EM ( $a^2 = 66\%$ ) and SEM ( $a^2 = 66\%$ ). The influence of individual environment explains the remaining 40% and 34% of variance of ST scale and the emotional sensitivity scales, respectively.

## Discussion

The obtained results point to significant differences in the degree of genetic determination of temperament traits assessed by the C-STQ, from the absence of influence of hereditary factors on the variance of object-related ergonicity (ER), social ergonicity (SER), object-related plasticity (P), social plasticity (SP), object-related tempo (T), and control scale C, to a quite significant influence of hereditary factors on the social tempo (ST) and emotional sensitivity (EM and SEM) scales.

Despite the absence of other behavior genetic studies of C-STQ scales, there is a large amount of data on the genetics of temperament traits similar in terms of content. As is known, a comparison between STQ scales and the data of the EPI questionnaire developed by H.J. Eysenck and C.B.G. Eysenck (Eysenck, 1975) and used in convergent validation of the OST showed high correlations of extraversion with SER, SP, T, and ST, and of neuroticism with the emotional sensitivity scales (Rusalov, 1989). Factor analysis of the scales of the well-known temperament questionnaires by Strelau (STI-R; Strelau, Angleitner, Bantelmann, and Ruch, 1990), the EASI-III (Buss, and Plomin, 1975)

temperament questionnaire, the Dimensions of Temperament Survey-Revised (DOTS-R; Windle, and Lerner, 1986), and STQ (Rusalov, 1989) demonstrated that scales ER, P, T, and ST correlated positively with the activity level and tempo factor; scale SER, with the sociability scale; and scale SP, with the impulsiveness scale; both emotional sensitivity scales form the negative extreme of the emotional stability factor (Ruch, Angleitner, and Strelau, 1991).

Analysis of the models' fit to the observed statistics shows that the differences in the degree of intra-pair similarity in the MZ and DZ twins for scales ER, SER, P, SP, T, and C can be explained by nonsystematic factors or a systematic error of method.

Among the models testing the significance of the various variance components, the environmental model provides the best fit to the data for these scales. These results are discrepant from the data of most twin studies of temperament, which point to a significant contribution of genetic factors and, as a rule, to the absence of a contribution of common environment to the development of individual differences temperamental traits at different stages of ontogenesis, including adolescence (Loehlin, 1992; Saudino, et al., 1995; Macaskill, et al., 1994; Eaves, et al., 1989). Generally speaking, these data indicate the absence of the genetic component in the structure of phenotypic variance of scales ER, SER, P, SP, T, and C.

As was noted above, scales SER, SP, and T are closely related to extraversion; however, data on hereditary determination of extraversion differ from data on the influence of heredity on these scales. The findings of twin studies that used adolescents' self-reports suggest significant genetic influences on extraversion variability. The same studies showed that family environment plays an insignificant part in the variability of this characteristic. In a study involving 262 twin pairs aged 7 – 17, the extraversion heritability coefficient was 0.50 (Eaves, et al., 1989). The results of model fitting showed that extraversion variability is determined by additive genetic factors, whereas the remaining part of variance is due to the individual environment component. A study involving Australian adolescent twins (1400 pairs aged 11 – 18) also demonstrated that extraversion data is best described by the model including additive genetic influences and individual environment factors (Macaskill, et al., 1994).

Scales ER, P, and T also correlate positively with the activity level scale, and scale SER, with the sociability scale of questionnaire EAS



(Buss, and Plomin, 1975). Table 2 presents results yielded by a number of twin studies, in which the parents rated the prominence of temperamental features of children and adolescents through the EAS questionnaire.

Table 2

**Intraclass correlation of temperamental parameters (Caspi, 1998)**

Average age of twins (years)	Temperamental parameters					
	Emotionality		Activity level		Sociability	
	MZ	DZ	MZ	DZ	MZ	DZ
1,5 years (Plomin et al., 1993)	0.43	-0.03	0.55	-0.24	0.44	0.07
5.0 years (Buss, and Plomin, 1984)	0.63	0.12	0.62	-0.13	0.53	-0.03
8.5 years (Matheny, and Dolan, 1980)	0.45	0.11	0.56	0.06	0.66	0.19
10-18 years (Saudino et al., 1995)	0.56	0.27	0.73	0.19	0.52	0.05

The results of the studies presented in Table 2 suggest significant influence of genetic factors on individual differences as regards emotionality, activity level, and sociability. K. Saudino, et al. (1995) used combined twin and family design (708 pairs of siblings with different degrees of family relationship – MZ and DZ twins, full siblings, half siblings, and adoptive siblings) to assess the hereditary determination of the parameters of emotionality, activity level, sociability (EAS) and shyness. In the twin model, the highest estimates of heredity were received for the activity level, 70% (mother ratings) and 80% (father ratings). The estimates of heredity for the sociability were somewhat lower, 55% (mother ratings) and 64% (father ratings). An analysis of the findings showed the absence of common environmental influence for both parameters. In the non-twin model, no contribution of genetic factors to the variability of the activity level was revealed, whereas for the sociability only the fathers' ratings gave a significant heritability estimate (56%) The influence of common environment was insignificant for both temperament traits.

As was noted above, the findings of the study revealed a significant contribution of the genotype to the individual differences in the social tempo (ST) and both emotional sensitivity scales (EM and SEM).

Content analysis of the questions on the ST scale shows that they are directed at assessing the speed and fluency of the speech, the ease of understanding rapid speech (*Do you find it easy to understand rapid speech? (# 25) Do you usually speak freely, without stumbling? (#41) Can you speak rapidly and legibly? (# 55) Do you read aloud rapidly? (# 70)*), as well as verbal-motor activity (*Do you prefer to speak slowly and unhurriedly? (# 9) Are you a talkative person? (# 40) Do you get tired talking fast? (# 100)*). Similar questions are used to diagnose extraversion in EPI (Eysenck, and Eysenck, 1975) and activity level in the EAS questionnaire by Buss and Plomin (1975). The heritability estimate for ST obtained in this study is 60%, which is consistent with the findings of genetic studies of extraversion (Eaves, et al., 1989; Loehlin, 1992; Macaskill, et al., 1994) and activity level (Saudino, et al., 1995). Genetic analysis of the data of ST shows that the observed data are best fitted by the simple genetic model, which is also true for most behavior genetic studies on extraversion (Eaves, et al., 1989; Loehlin, 1992; Macaskill, et al., 1994) and activity level (Saudino, et al., 1995).

Similar results were also obtained for the indicators of object-related (EM) and social (SEM) emotional sensitivity. It should be noted that the emotional sensitivity scales diagnose a construct that is close, in terms of content, to the parameters of neuroticism (Eysenck, and Eysenck, 1975) and emotionality (Buss, and Plomin, 1975). The C-STQ EM scale is designed to assess negative emotional sensations in situation connected with learning (*Do you experience the feeling of uncertainty preparing your homework? (# 71) Do you suffer from insomnia if something goes wrong at school? (# 72) Do you become very anxious because of the mistakes made in a test? (# 102)*), and scale SEM – in situations of social interaction (*Do you suffer from lack of self-confidence when mixing with people? (# 104)*). The heritability estimates obtained in this study are the same for both emotional sensitivity scales and equal 66%. These figures coincide with the results obtained in the twin study of emotionality diagnosed through the EAS questionnaire (Saudino, et al., 1995). In the study by Saudino, et al. (1995), the heritability estimates for the emotionality were 60% (mothers ratings) and 68% (fathers ratings). The non-twin model also yielded significant heritability estimates obtained on the basis of the mothers (16%) and the fathers (56%) ratings. Twin studies for neuroticism in adulthood and older adolescence revealed lower heritability estimates, about 40% (Loehlin, 1992). The data for the EM and SEM scales obtained in our

study are best described by the simple genetic model; this is also true in most studies on neuroticism (Eaves, et al., 1989) and emotionality assessed through EAS (Saudino, et al., 1995). No influence of common environment was discovered in our or other studies, which testifies to the absence of influence of common family environment (socio-economical status and other formal characteristics of the family, the same parenting style, etc.) on the intra-pair similarity for these traits. At the same time, individual environment plays a significant part in the formation of differences in emotionality level. The possible sources of individual experience include random factors, the specifics of siblings' relationships, family structure, the parents' treatment of the children, and peer relationships (Plomin, Chipuer, and Neiderhiser, 1994).

It is easy to see that the obtained data point to significant hereditary determination of individual ST, EM, and SEM differences, unlike ER, SER, P, SP, and T, which are formed under the influence of environmental factors in adolescents aged 13–14.

As is known, any genetic influence upon behavioral characteristics is realized through the morphophysiological level (biochemical, physiological, etc.); this is probably why the temperamental traits identified in the temperament models which factor in this level more frequently reveal hereditary determination. For example, the physiological mechanisms that underlie extraversion and introversion are believed to be constituted by ascendant activating effects of the reticular formation (Eysenck, 1991). The differences in the level of neuroticism are regarded as differences in the level of activation of the visceral brain (Eysenck, 1991). C. Cloninger's psychobiological temperament model is based on the features of the dopamine, norepinephrine and serotonin brain systems (Cloninger, 1987). As was noted above, genetic studies of temperamental traits identified within the framework of these models point to a significant contribution of heredity.

The C-STQ scale also rests on the concept of biological determination of the formal-dynamic features of individual human behavior. Nevertheless, genetic influences were revealed only for the social tempo (ST) indicators and both emotional sensitivity scales (EM and SEM), which intersect, as regards content, with the indicators of neuroticism and extraversion. The social tempo parameter reflects one of the aspects of extraversion and activity level, that connected with the intensity, tempo, frequency and duration of verbal actions (Buss, and Plomin, 1975;

Nebylitsin, 1976; Strelau, 1982; Buss, and Plomin, 1975). The parameters of object-related and social emotional sensitivity reflect individual emotional stability and are close to the notions of neuroticism and emotionality (Buss, and Plomin, 1975; Nebylitsin, 1976; Strelau, 1982).

Despite the fact that they also reveal links with the indicators of extraversion and activity level, the individual differences in ER, SER, P, SP, T, and C dimensions form under the influence of environment. These data point to the heterogeneous nature of these characteristics and, correspondingly, to the need for the C-STQ scales validation as constructs.

According to Rusalov's theoretical assumption (Rusalov, 1979; 1992), hereditary determination is a basis for defining an individual characteristic as a temperamental trait. Consequently, out of the proposed eight-factor structure, three can be treated as temperamental dimensions, namely, social tempo (ST), object-related emotional sensitivity (EM), and social emotional sensitivity (SEM), since significant heritability assessments were obtained for these parameters alone. The high degree of inner consistency of the other C-STQ scales testifies to their reliability. However, the constructs that are diagnosed by these scales are less determined by individual's natural predispositions and cannot, therefore (according to Rusalov), be treated as temperamental features. These scales are more determined by personality traits and the content of activity.

A number of studies of STQ construct validity also indicated the need to specify the structure of the questionnaire. Although the factor analysis of 105 points of the STQ conducted by Dumenci (1996) did not reveal an eight-factor structure of the questionnaire, the three-factor solution at the level of individual points coincided with the results of Rusalov's factor analysis of the scale scores (Rusalov, 1992). These results made Dumenci (1996) conclude that the structure of STQ is more adequately described by three temperament scales whose names were originally suggested by Rusalov (1992): object-oriented activity (scales ER, P, and T), emotionality (scales EM and SEM), and communicative (scales SER, SP, and ST).

## References

- Babynin, E.V. (2003). Geneticheskie aspekty temperamenta [The Genetic Aspects of Temperament]. *Psikhologicheskii zhurnal*, 24, 5. P. 95 – 102.
- Benjamin, J., Ebstein, R.P., and Belmaker, R.H. (eds.) (2002). *Molecular genetics and the human personality*. Washington: American Psychiatric Publishing, Inc.

- Bollen, K.A. (1989). *Structural Equations with Latent Variables*. New York: John Wiley.
- Borkenau, P., Riemann, R., Angleitner, A., and Spinath, F.M. (2001). Genetic and environmental influences on observed personality: Evidence from the German Observational Study of Adult Twins. *Journal of Personality and Social Psychology*, 80. P. 655-668.
- Braungart, J.M., Plomin, R., DeFries, J.C., and Fulker, D.W. (1992). Genetic influence on tester-rated infant temperament as assessed by Bayley's Infant Behavior Record: Nonadoptive and adoptive siblings and twins. *Developmental Psychology*, 28. P. 40-47.
- Buss, A.H., and Plomin, R. (1975). *A temperament theory of personality development*. Oxford: Wiley-Interscience.
- Buss, A.H., and Plomin, R. (1984). *Temperament: Early developing personality traits*. Hillsdale: Erlbaum.
- Capaldi, D.M., and Rothbart, M.K. (1992). Development and validation of an early adolescent temperament measure. *Journal of Early Adolescence*, 12. P. 153-173.
- Caspi, A. (1998). Personality development across the life course. In W. Damon (Ser. Ed.) and N. Eisenberg (Vol. Ed.). *Handbook of Child Psychology*. Vol. 3: *Social, emotional, and personality development*. New York: Wiley. P. 311-388.
- Cherny, S.S., Fulker, D.W., Emde, R.N., Robinson, J., and et al (1994). A developmental-genetic analysis of continuity and change in the Bayley Mental Development Index from 14 to 24 months: The MacArthur Longitudinal Twin Study. *Psychological Science*, 5. P. 354-360.
- Cherny, S.S., Fulker, D.W., Corley, R.P., et al (1994). Continuity and change in infant shyness from 14 to 20 months. *Behavior Genetics*, 24. P. 365-379.
- Cloninger, C.R. (1987). A systematic method for clinical description and classification of personality variants: A proposal. *Archives of General Psychiatry*, 44. P. 573-588.
- Cohen, D.J., Dibble, E., Grawe, J.M., and Pollin, W. (1973). Separating identical from fraternal twins. *Archives of General Psychiatry*, 29. P. 465-469.
- Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16. P. 297-334.
- DiLalla, L.F., and Jones, S. (2000). Genetic and environmental influences on temperament in preschoolers. In V.J. Molfese, and D.L. Molfese (eds). *Temperament and personality development across the life span*. Mahwah: Lawrence Erlbaum Associates, Publishers. P. 33-55.
- Dumenci, L. (1996). Factorial validity of scores on the Structure of Temperament Questionnaire. *Educational and Psychological Measurement*, 56. P. 487-493.
- Eaves, L.J., Eysenck, H.J., and Martin, N.G. (1989). *Genes, culture and personality: An empirical approach*. San Diego: Academic Press.
- Emde, R.N., Plomin, R., Robinson, J., et al. (1992). Temperament, emotion, and cognition at fourteen months: The MacArthur Longitudinal Twin Study. *Child Development*, 63. P. 1437-1455.

- Eysenck, H.J., and Eysenck, S.B.G. (1975). *Manual for the Eysenck Personality Questionnaire*. San Diego: EDITS.
- Eysenck, H.J. (1981). General features of the model. In H.J. Eysenck (ed.). *A model for personality*. New York: Springer-Verlag. P.1-37.
- Eysenck, H.J. (1991). Dimensions of personality: The biosocial approach to personality. In J. Strelau, and A. Angleitner (eds.). *Explorations in temperament: International perspectives on theory and measurement. Perspectives on individual differences*. New York: Plenum Press. P. 87-103.
- Finkel, D., and McGue, M. (1997). Sex differences and nonadditivity in heritability of the Multidimensional Personality Questionnaire Scales. *Journal of Personality and Social Psychology*, 72. P. 929-938.
- Fisher, R.A. (1918). The correlation between relatives on the supposition of Mendelian inheritance. *Transactions of the Royal Society of Edinburgh*, 52. P. 399-433.
- Floderus-Myrhed, B., Pedersen, N., and Rasmuson, I. (1980). Assessment of heritability for personality, based on a short-form of the Eysenck Personality Inventory: A study of 12, 898 twin pairs. *Behavior Genetics*, 10. P.153-162.
- Fulker, D.W., Eysenck, S.B., and Zuckerman, M. (1980). A genetic and environmental analysis of sensation seeking. *Journal of Research in Personality*, 14. P. 261-281.
- Gagne, J.R., Saudino, K.J., Cherny, S.S. (2003). Genetic influences on temperament in early adolescence. In S.Petrill, R.Plomin, et al. (eds.). *Nature, nurture and the transition to early adolescence*. Oxford: University press. P. 166-184.
- Gjone, H., and Stevenson, J. (1997). A longitudinal twin study of temperament and behavior problems: Common genetic or environmental influences? *Journal of the American Academy of Child and Adolescent Psychiatry*, 36. P. 1448-1456.
- Goldsmith, H.H., Buss, K.A., and Lemery, K.S. (1997). Toddler and childhood temperament: Expanded content, stronger genetic evidence, new evidence for the importance of environment. *Developmental Psychology*, 33. P. 891-905.
- Goldsmith, H.H., and Campos, J.J. (1982). Toward a theory of infant temperament. In R.N. Emde, and R.J. Harmon (eds.). *The development of attachment and affiliative systems*. New York: Plenum Press. P. 161-193.
- Goldsmith, H.H., and Campos, J. (1986). Fundamental issues in the study of early temperament: The Denver Twin Temperament Study. In M.E. Lamb, A.L. Brown, and B. Rogoff (eds.). *Advances in developmental psychology*, 4. Hillsdale: Erlbaum. P. 231-283.
- Gray, J.A. (1982). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system*. New York: Clarendon Press; Oxford: University Press.
- Henderson, N.D. (1982). Human behavior genetics. *Annual Review of Psychology*, 33. P. 403-440.
- John, O.P. (1990). The "Big Five" factor taxonomy: Dimensions of personality in the natural language and in questionnaires. In A.L. Pervin (ed.). *Handbook of personality: Theory and research*. New York: Guilford Press. P. 66-100.

- Kohnstamm, G.A., Bates, J.E., and Rothbart, M.K. (eds.) (1989). *Temperament in childhood*. Oxford: John Wiley and Sons.
- Koopmans, J.R., Boomsma, D.I., et al (1995). A multivariate genetic analysis of sensation seeking. *Behavior Genetics*, 25. P. 349-356.
- Krupnov, A.I. (1992). *Psihologicheskie proyavleniya i struktura temperamenta [Psychological Manifestations and the Structure of Temperament]*. Moskva: Izdatelstvo Rossijskogo Universiteta druzhby narodov.
- Loehlin, J.C. (1987). *Latent Variable Models: An Introduction to Factor, Path, and Structural Analysis*. Hillsdale: Erlbaum.
- Loehlin, J.C. (1992). Genes and environment in personality development. *Sage series on individual differences and development*, 2. Thousand Oaks: Sage Publications, Inc.
- Loehlin, J.C., and Nichols, R.C. (1976). *Heredity, environment and personality*. Austin: University of Texas Press.
- Macaskill, G.T., Hopper, J.L., White, V., and Hill, D.J. (1994). Genetic and environmental variation in Eysenck Personality scales measured on Australian adolescent twins. *Behavior Genetics*, 24. P. 481-491.
- Matheny, A.P., and Dolan, A.B. (1980). A twin study of personality and temperament during middle childhood. *Journal of Research in Personality*, 14. P. 224-234.
- Matheny, A.P. (1980). Bayley's Infant Behavior Record: Behavioral components and twin analyses. *Child Development*, 51. P. 1157-1167.
- Matheny, A.P. (1983). A longitudinal twin study of stability of components from Bayley's Infant Behavior Record. *Child Development*, 54. P. 356-360.
- Matheny, A.P. (1984). Twin similarity in the developmental transformations of infant temperament as measured in a multi-method, longitudinal study. *Acta Geneticae Medicae et Gemellogiae*, 33. P. 181-189.
- Matheny, A.P. (1989). Children's behavioral inhibition over age and across situations: Genetic similarity for a trait during change. *Journal of Personality*, 57. P. 215-235.
- McCrae, R.R., and Costa, P.T. (1990). *Personality in adulthood*. New York: Guilford Press.
- Neale, M.C., and Cardon, L.R. (1992). *Methodology for genetic studies of twins and families*. Norwood: Kluwer Academic.
- Neale, M.C., Kessler, R.C., Eaves, L.J., and Kendler, K.S. (1992). Evidence for genetic influences on personality from self-reports and informant ratings. *Journal of Personality and Social Psychology*, 63. P. 85-96.
- Nebylitsin, V.D. (1976). *Psihofiziologicheskie issledovaniya individual'nyh razlichij [Psychophysiological Studies of Individual Differences]*. Moskva.
- Norman, W.T. (1963). Toward an adequate taxonomy of personality attributes: Replicated factor structure in peer nomination personality ratings. *Journal of Abnormal and Social Psychology*, 66, 6. P. 574-583.
- Plomin, R., Chipuer, H.M., and Loehlin, J.C. (1990). Behavioral genetics and personality. In L.A. Pervin (ed.). *Handbook of personality: Theory and research*. New York: Guilford Press. P. 225-243.

- Plomin, R., Chipuer, H.M., and Neiderhiser, J.M. (1994). Behavioral genetic evidence for the importance of nonshared environment. In E.M. Hetherington, D. Reiss, and et al (eds.). *Separate social worlds of siblings: The impact of nonshared environment on development*. Hillsdale: Lawrence Erlbaum Associates, Inc. P. 1-31.
- Plomin, R., Emde, R.N., Braungart, J.M., et al (1993). Genetic change and continuity from fourteen to twenty months: The MacArthur Longitudinal Twin Study. *Child Development*, 64. P. 1354-1376.
- Riemann, R., Angleitner, A., and Strelau, J. (1997). Genetic and environmental influences on personality: A study of twins reared together using the self- and peer-report NEO-FFI scales. *Journal of Personality*, 65. P. 449-475.
- Riese, M.L. (1990). Neonatal temperament in monozygotic and dizygotic twin pairs. *Child Development*, 61. P. 1230-1237.
- Rose, R.J. (1995). Genes and human behavior. *Annual Review of Psychology*, 46. P. 625-654.
- Rose, R.J., Koskenvuo, M., Kaprio, J., Sarna, S., and Langinvainio, H. (1988). Shared genes, shared experiences, and similarity of personality: Data from 14,228 Finnish co-twins. *Journal of Personality and Social Psychology*, 54. P. 161-171.
- Rothbart, M.K., and Derryberry, D. (1981). Development of individual differences in temperament. In M.E. Lamb and A.L. Brown (eds.). *Advances in developmental psychology*, 1. Hillsdale: Erlbaum. P. 37-86.
- Ruch, W., Angleitner, A., and Strelau, J. (1991). The Strelau Temperament Inventory-Revised (STI-R): Validity studies. *European Journal of Personality*, 5. P. 287-308.
- Rusalov, V.M. (1979). *Biologicheskie osnovy individual'no-psihologicheskikh razlichij [The Biological Foundations of Individual-psychological Differences]*. Moskva: Nauka.
- Rusalov, V.M. (1992). *Oprosnik struktury temperamenta. Metodologicheskij uchebnik [A Temperament Structure Questionnaire. Methodological manual]*. Moskva: Smysl.
- Saudino, K.J., and Eaton, W.O. (1991). Infant temperament and genetics: An objective twin study of motor activity level. *Child Development*, 65. P.1167-1174.
- Saudino, K.J., and Eaton, W.O. (1995). Continuity and change in objectively assessed temperament: A longitudinal twin study of activity level. *British Journal of Developmental Psychology*, 13. P. 81-95.
- Saudino, K.J., McGuire, S., Reiss, D., et al (1995). Parent ratings of EAS temperaments in twins, full siblings, half siblings, and step siblings. *Journal of Personality and Social Psychology*, 68. P. 723-733.
- Saudino, K.J., Plomin, R., and DeFries, J.C. (1996). Tester-rated temperament at 14, 20 and 24 months: Environmental change and genetic continuity. *British Journal of Developmental Psychology*, 14. P. 129-144.
- Saudino K., Cherny S.S. (2001). Sources of continuity and change in observed temperament. In R. Emde, J.K. Hewitt (eds.). *Infancy to early childhood. Genetic and environmental influences on developmental change*. Oxford: University Press. P. 89-110.



- Spinath, F.M., and Angleitner, A. (1998). Contrast effects in Buss and Plomin's EAS questionnaire: A behavioral-genetic study on early developing personality traits assessed through parental ratings. *Personality and Individual Differences*, 25. P. 947-963.
- Stallings, M.C., Hewitt, J.K., Cloninger, C.R., et al. (1996). Genetic and environmental structure of the Tridimensional Personality Questionnaire: Three or four temperament dimensions? *Journal of Personality and Social Psychology*, 70. P. 127-140.
- Strelau, J. (1982). *Roľ temperamenta v psihicheskom razvitii [The Role of Temperament in Mental Development]*. Moskva: Progress.
- Strelau, J., and Angleitner, A. (1991a). Introduction. In J. Strelau, and A. Angleitner (eds.). *Explorations in temperament: International perspectives on theory and measurement. Perspectives on individual differences*. New York: Plenum Press. P. 1-12.
- Strelau, J., and Angleitner, A. (eds.) (1991b). *Explorations in temperament: International perspectives on theory and measurement*. New York: Plenum Press.
- Strelau, J., Angleitner, A., Bantelmann, J., and Ruch, W. (1990). The Strelau Temperament Inventory-Revised (STI-R): Theoretical considerations and scale development. *European Journal of Personality*, 4. P. 209-235.
- Stroganova, T.A., Tsetlin, M.M., Malykh, S.B., and Malakhovskaya, E.V. (2000). Biological principles of individual differences of children of the second half-year of life: Communication II. The nature of individual differences in temperamental features. *Human Physiology*, 26. P. 281-289.
- Tellegen, A., Lykken, D.T., et al (1988). Personality similarity in twins reared apart and together. *Journal of Personality and Social Psychology*, 54. P. 1031-1039.
- Teplov, B.M. (1985). *Izbrannye trudy v 2 tomakh [Selected Works in 2 vols.]*. Moskva: Pedagogika.
- Torgersen, A.M. (1987). Longitudinal research on temperament in twins. *Acta Geneticae Medicae et Gemellologiae: Twin Research*, 36. P.145-154.
- Torgersen, A.M. (1989). Genetic and environmental influences on temperament development: Longitudinal study of twins from infancy to adolescent. In S. Doxiadis, and S. Stewart (eds.). *Early influences shaping the individual*. New York: Plenum Press. P. 269-282.
- Viken, R.J., Rose, R.J., Kaprio, J., and Koskenvuo, M. (1994) A Developmental Genetic Analysis of Adult Personality: Extraversion and Neuroticism From 18 to 59 Years of Age. *Journal of Personality and Social Psychology*, 66. P. 722-730.
- Wilson, R.S., and Matheny, A.P., Jr. (1986). Behavior genetics research in infant temperament: The Louisville Twin Study. In R. Plomin and J.F. Dunn (eds.). *The study of temperament: Changes, continuities, and challenges* Hillsdale: Erlbaum. P. 81-97.
- Windle, M., and Lerner, R.M. (1986). Reassessing the dimensions of temperamental individuality across the life span: The Revised Dimensions of Temperament Survey (DOTS-R). *Journal of Adolescent Research*, 1. P. 213-229.
- Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. New York: Cambridge University Press.