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Heritability of Interests: A Twin Study

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The authors administered inventories of vocational and recreational interests and talents to 924 pairs of twins who had been reared together and to 92 pairs separated in infancy and reared apart. Factor analysis of all 291 items yielded 39 identifiable factors and 11 superfactors. The data indicated that about 50% of interests variance (about two thirds of the stable variance) was associated with genetic variation. The authors show that heritability can be conservatively estimated from the within-pair correlations of adult monozygotic twins reared together. Evidence for nonadditive genetic effects on interests may explain why heritability estimates based on family studies are so much lower. The authors propose a model in which precursor traits of aptitude and personality, in part genetically determined, guide the development of interests through the mechanisms of gene–environment correlation and interaction.

"Although there is evidence for the contribution of genetic factors to interests, these factors account for less than 5% of interests variance" (Gati, 1991, p. 312). This summary appraisal, in a recent and authoritative article, seems to represent the prevailing view among professionals involved in the study of interest measurement and its applications in vocational selection and counseling. This view, however, is mistaken. Several earlier studies not cited by Gati (e.g., Loehlin & Nichols, 1976; Roberts & Johansson, 1974; Vandenberg & Stafford, 1967), studies of twins reared together who were either college students or 11th-grade Merit Scholarship aspirants when tested, suggested heritabilities on the order of 36% for the major interest factors in these populations (cf. Nichols, 1978).

More recently, Moloney, Bouchard, and Segal (1991) examined interest-test scores of 45 pairs of monozygotic (MZ) twins separated in infancy and reared apart (MZA twins) and of 22 pairs of same-sex dizygotic (DZ) twins separated in infancy and reared apart (DZA twins). These separated twins, who ranged in age from 12 to 70 years when tested, had completed the Strong Vocational Interest Blank (SVIB) and also the Jackson Vocational Interest Survey (JVIS). For the 34 scales of the JVIS and the 23 basic interest scales of the SVIB, the mean heritability estimates were .37 and .44, respectively. For the 10 principal components underlying the total set of 57 scales, the age- and sex-corrected MZA intraclass correlations, which directly estimate broad heritability, ranged from .25 (SE = .14) to .73 (SE = .07; median r = .50, SE = .11). The DZA correlations on these superfactors of occupational interest ranged from −.07 (SE = .21) to .30 (SE = .20; median r = .03, SE = .21).

These results suggest that variation in occupational interests may, in fact, be quite strongly associated with genetic variation. Moreover, for such factors as Artistic, for which the MZA correlation was .52 but the DZA value was only −.07, these data suggest that certain interests may be "emergenic" (Li, 1987; Lykken, 1982). An emergenic trait is one for which the relevant polygenes contribute configurally (i.e., epistatically), rather than in an additive fashion, with the result that, although genetically determined, emergenic traits may not run in families (Lykken, McGue, Tellegen, & Bouchard, 1992).

Because of the rarity of twins reared apart, these samples were small. Yet, because of the power of the MZA design for estimating heritabilities, the statistical reliability of these findings is comparable to those based on nearly 20 times as many pairs of MZ and DZ twins reared together (Lykken, Geisser, & Tellegen, 1981). Nevertheless, like all findings with important implications, these results require constructive replication (Lykken, 1968) with additional samples and different instruments.

Waller, Lykken, and Tellegen (in press) administered new inventories of occupational and leisure-time interests to a large sample of adult participants in the Minnesota Twin Family Registry (Lykken, Bouchard, McGue, & Tellegen, 1990). The mean age of these subjects when tested was 39.5 years (SD = 11.3 years) and 37.6 years (SD = 10.4 years) for the men and women, respectively. There were 1,768 men and 2,311 women in the tested sample, of whom about two thirds were twins; the remaining one third were spouses or first-degree relatives of the twins. Because the inventories used by Waller et al. were also used in the present research, they are more fully described later in this article. Factor analyses based on the more than 4,000 subjects revealed 17 occupational interest factors and 18 leisure-time interest factors that were congruent for both sexes. Heritabilities for the occupational interests ranged from .00 to .56 (median r = .42). These values were very similar to those reported for MZA twins by Moloney et al. (1991) for the scales of

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the SVIB and the JVIS. For the leisure-time interests, Waller et al. found heritabilities ranging from .20 to .63 (median $r = .47$).

Estimating Heritability From MZ-Twin Correlations

Twin studies commonly use the Falconer (1960) formula (or its maximum likelihood equivalent), Falconer $h^2 = 2(R_{MZT} - R_{DZT})$, where h^2 is an estimate of narrow-sense heritability (the proportion of observed variance associated with additive genetic variance), whereas R_{MZT} and R_{DZT} are the within-pair intraclass correlations for MZT and DZT twins, respectively, and T indicates twins who have been reared together. R_{DZT} is included in the formula for the purpose of removing from R_{MZT} the covariance resulting from the twins having shared a common rearing environment.

For most psychological traits, however, it has been found that, for adult twins, R_{MZA} and R_{MZT} are substantially equal, indicating that a common rearing environment has negligible lasting effect (Bouchard, Lykken, McGue, Segal, & Tellegen, 1990; Plomin & Daniels, 1986). Near equivalence of R_{MZT} with R_{MZA} has been shown for traits of personality (Bouchard & McGue, 1990; Tellegen et al., 1988), for religiosity (Waller, Kojetin, Bouchard, Lykken, & Tellegen, 1990), and for various psychophysiological traits (Lykken, Iacono, Haroian, McGue, & Bouchard, 1988). The absence of similarity among biologically unrelated adults who have been reared together further confirms the lack of a lasting common-rearing effect (Plomin & Daniels, 1986). For example, the mean correlation in adult IQ for 289 pairs of unrelated persons reared together was −.01 (Bouchard, Lykken, McGue, & Tellegen, 1992). The most recent study of IQ in MZA twins involved 46 Swedish pairs who averaged over 65 years of age when tested; their IQ correlation was .78, compared with .80 for an age-matched group of MZ twins reared together (Pedersen, Plomin, Nesselroade, & McClearn, 1992). Any slight excess of the MZT over the MZA value, if it exists, can be attributed to *passive gene–environment correlation* (passive COV_{ge}; Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). An illustration of passive COV_{ge} in the interests domain would be the tendency for parents who are interested in athletics to contribute to their offspring not only their genes but also an environment conducive to the development of athletic interests. This component of trait variance is largely missing in twins reared apart.

It is natural (and correct) to suppose that MZ twins, because they are so similar, are likely to elicit similar treatment from their parents, teachers, and peers and are likely to seek out similar experiences and to respond in a similar way to the same experiences; these effects are referred to as *reactive* and *active gene–environment correlation* and as *gene–environment interaction*, respectively (Plomin et al., 1977; Scarr & McCartney, 1983). The similarity of MZA and MZT twins shows, however, that these centripetal influences work nearly as well when the twins are reared as singletons in different families, unaware of each other's existence, as when they are reared in the same family. As Scarr (1992) has pointed out, the family is not the "unit of environmental transmission," because "ordinary differences between families have little effect on children's development, unless the family is outside of the normal developmental range" (p. 16) McCartney, Harris, and Bernieri (1990) have shown that the modest effects of common rearing that are observed for some traits when assessed in childhood or adolescence attenuate toward zero as the youngsters mature and move apart.

Because the truly formative experiences that do have a lasting effect are elicited or sought out in response to the child's genetic characteristics and proclivities, their influence is counted as part of the genetic component of trait variance, specified as *gene–environment covariance* or *interaction*. Thus, MZ twins who are physically robust and well coordinated are likely to become interested in sports, whether they are reared in the same or different households. Other studies of large samples of adult MZT and DZT twins agree in finding little evidence that shared rearing environment increases twin similarity in adulthood; structural models that include a component of shared environmental variance rarely fit the data better than models that include only genetic and nonshared environmental variance (e.g., Eaves, Eysenck, & Martin, 1989; Pedersen, Plomin, McClearn, & Friberg, 1988).

For twins reared apart, R_{MZA} directly estimates broad-sense heritability, including both additive and nonadditive genetic effects. Estimates of heritability based on the Falconer formula are far less reliable than those based on R_{MZA} (Lykken et al., 1981) and also overestimate heritability when nonadditive variance is involved (e.g., in the case of emergenic traits). In the absence of lasting effects of shared rearing environment, $R_{MZT} \approx R_{MZA}$; therefore, because MZA twins are not commonly available, R_{MZT} may provide the most reliable and conservative estimate of trait heritability.

Goals of the Present Study

It seems reasonable to suppose that one's desire to engage in various occupational and recreational activities might be influenced by one's assessment of one's own talents and abilities. DeNisi and Shaw (1977) showed that college students can predict their own relative scores on various aptitude tests with only modest accuracy, but, as we show, people can produce stable self-assessments with respect to more familiar and visible talents. Moreover, it may be the individual's self-assessed talent, more than his or her veridical talent, that influences the pattern of interests. In addition to the interest inventories analyzed by Waller et al. (in press), the Twin Registry subjects also completed a set of 71 items inquiring about talents and other such personal characteristics. The present study focused on this larger item set and on a subgroup of the twins used by Waller et al. who were asked to retake the inventories approximately 3 years after the first administration. These data permitted us to test a simple model of interest traits.

We assumed, first, that vocational and recreational interests are influenced by self-assessed talents and related attributes so that the three classes of self-report items would combine in sensible ways in a joint factor analysis. We have shown that factors of personality vary unsystematically over time and that it is the stable component that is heritable (McGue, Bacon, & Lykken, 1993). In the same way, we suggest that the measured value of an interest–talent trait can be said to consist of three components: (a) a stable component that reflects a fixed (but not necessarily valid) impression as to what the activity in ques-

tion is like and, perhaps, of one's native talent for that activity; (b) a transitory component that reflects situational or state variables; and (c) a component of measurement error. Because it is the stable component of interests that should be most strongly influenced by genetic factors, the broad heritability of the stable component, estimated from the average of repeated measurements, should be higher than the heritability estimated from measurements made on a single occasion.

On the basis of this model, and given sets of items (described below) that were broadly representative of vocational interests, of leisure-time interests, and of the talents and personal characteristics that might be expected to influence such interests, we administered these items to a large sample of mature MZT and DZT twins and to a modest sample of MZA and DZA twins. We readministered the items to a subsample of the MZT and DZT twins after a 3-year interval, and we now propose the following questions for investigation:

1. Do the three types of items intercorrelate so as to produce interest factors combining vocational and leisure interests with relevant self-assessed talents and personal characteristics?
2. Do MZT-twin correlations on interest–talent traits provide good estimates of the heritabilities of those traits?
3. Do estimates of the heritability of interest–talent traits increase with the retest stability of the measures on which they are based?
4. Do heritability estimates increase as the measures on which they are based increase in alpha reliability and more adequately assess some single underlying variable?
5. Is there evidence in the interest–talent domain for nonadditive genetic variance, that is, for emergenic traits, the heritability of which would be underestimated by family studies?

Method

Subjects

The Minnesota Twin Family Registry consists of twins born in Minnesota from 1936 through 1955 (Lykken et al., 1990). All twins were ascertained through birth records, and 80% of the surviving, intact pairs have been successfully located and recruited for participation in various studies. Spouses and, in some cases, parents, siblings, or young adult offspring of these twins were also recruited. Zygosity diagnosis was by mailed questionnaire; on the basis of a subsample that received extensive serological analysis, the accuracy of this zygosity determination has been estimated to be in excess of 95% (Lykken et al., 1990). Same-sex twins from 6 of the 20 birth years (1936, 1937, 1938, 1949, 1954, and 1955) were the first to be recruited and provided the data on which the present research was based. The group comprised 820 male twins, including 306 concordant (i.e., both twins participating) pairs; 1,388 female twins, with 618 concordant pairs; 1,089 spouses; 293 parents of the younger twins; 303 offspring of the older twins; and 186 siblings—a total of 1,768 men and 2,311 women. Of the 924 pairs who were concordant for completing all tests, 618 (67%) were female pairs and 524 pairs (57%) were MZ pairs, whereas 400 were same-sex DZ pairs. At the time of first testing, the twins ranged in age from 29 to 55 years.

Subjects were sent a booklet containing five inventories to be completed at home and returned by mail. These included the 300-item Multidimensional Personality Questionnaire (Tellegen & Waller, in press), which contains a set of validity keys to detect random or inconsistent responding. Subjects for whom these keys indicated dubious validity were discarded from all analyses, along with a few additional subjects who failed to answer 10 or more of the 291 inventory items, leaving 903 usable concordant pairs.

Of the twin pairs who were concordant for completing all five tests (72% of the participating pairs), 240 pairs were asked to retake the last four inventories approximately 3 years after the first testing. Complete returns were obtained from both members of 198 pairs: 53 MZ and 52 DZ female pairs and 49 MZ and 44 DZ male pairs.

Finally, the same inventories were administered to 205 participants in the Minnesota Study of Twins Reared Apart (Bouchard et al., 1990): 34 MZA and 25 MZA female pairs, 19 MZA and 11 DZA male pairs, and one set of MZA male triplets. About one half of the reared-apart sample took the inventories under supervision at our laboratories, whereas the other half, who were originally studied before the inventories had been developed, received the inventories in the mail and completed them at home. The data from these reared-apart twins were not included in the factor analyses described below.

Measures

Minnesota Vocational Interests Test (MVIT). The MVIT consists of 100 items written to tap the broader factors of occupational interest that are commonly identified. Many of the items are composites (e.g., "skilled trades: appliance repair, auto mechanic, carpenter, electrician, plumber, etc." rather than separate items for "plumber" and "auto mechanic"); this practice yields richer items at the risk of conflating unrelated components. Subjects were asked to pretend that each occupation would

> provide you with the same income and the same respect in the community. Then rate each activity—LIKE, INDIFFERENT, DISLIKE—strictly according to how much you think you would enjoy that type of work and those working conditions. PRETEND ALL JOBS YIELD EQUAL PAY, EQUAL STATUS.

Minnesota Leisure-Time Interest Test (MLIT). The MLIT consists of 120 items describing a wide variety of leisure-time activities, such as "going fishing," "nightlife: bars, nightclubs, discos, etc.," "volunteer work," "taking a college course in some subject of interest," "going on a camera safari in Africa, Borneo, the desert, or the Amazon basin," or "getting involved in controversial issues." Once again, most of the items are stated rather generally, for example, "risky pastimes: hang gliding, mountain climbing, surfing, etc." Subjects were instructed to

> pretend that you are not limited by time, or money, or by age or health. Assuming that you *could* do any of these things, how often do you think that you *would* do them? Mark each activity with a number from 1 to 5 to indicate one of the following answers: Never, Seldom, Sometimes, Frequently, or Often as possible.

Minnesota Talent Survey (MTS) and Self-Rating Inventory (SRI). The MTS is a 40-item survey of familiar talents. The following are two representative items:

> *Carpentry:* (1) You can make furniture, cabinets, etc.; (2) You can hang a door, use power saws, build a dog house, etc.; (3) You can do minor repairs using hand tools; (4) You are unskilled with hammer or saw.
>
> *Self-Assertion:* (1) You are the kind of person that nobody would try to take advantage of; you can be forceful and intimidating when you have to be; (2) You can stand up for yourself and your interests better than most people; (3) Average; (4) You are easily taken advantage of, easily intimidated.

As these examples attest, the four alternatives are worded so that 1 represents outstanding or professional-level talent, 3 is the broad aver-

age region, and 4 is below average. The 40 items range widely (e.g., singing, athletics, buying and selling, public speaking, physical strength, personal appearance, witty, and cool headed). About 20% of the men rated themselves 1 in mechanics and carpentry compared with less than 1% of the women, whereas about 40% of the women rated themselves 1 in sewing and in cooking compared with only 2% and 5%, respectively, of the men. On the "well-oriented" item ("You are unusually good at finding your way around, reading maps; when other people get confused or lost, you know where you are"), 27% of the men gave themselves top ratings as compared with 9% of the women. Many of these talents (e.g., getting acquainted, making money, good persuader, and buying and selling) have obvious relevance to occupational choice.

The SRI consists of 31 items assessing qualities not directly addressed by the other items in the test battery. The following are two illustrative items:

> *Abstract Intelligence:* The ability to solve intellectual problems, to understand complicated issues, to figure things out; "school intelligence."
>
> *Self-Discipline:* High-scorers can make themselves do what needs to be done whether they enjoy it or not; if they decide to lose weight or to quit smoking or to learn Spanish, they will do it. They achieve the goals they set for themselves.

Subjects were asked to "compare yourself with other people—where do you think you would rank compared to other people of your age and sex?" using a 5-point scale demarcated thus: 1 = lowest 5%, 2 = lower 30%, 3 = middle 30%, 4 = upper 30%, 5 = highest 5%. Other items asked about creativity, mental energy, physical energy, morality, affability, and nurturance, attributes that also have obvious relevance to occupational choice.

Scaling

When we factor analyzed the interest items, the first principal component was strongly correlated with strength of interest averaged over all the items; people who expressed strong interest in many activities got high scores on this factor, whereas those who seldom expressed strong interests got low scores. Similarly, some people claimed strong endowment in many of the attributes listed in the MTS, whereas others claimed few and modest talents. Although there is undoubtedly some psychological truth in these differences—some people do have broader and more vigorous interests, some people are more talented in more respects than others are—so that this first factor is not merely response set, this strong common factor would tend to obscure the rest of the factorial structure unless hierarchical factor structures were used (e.g., Schmid & Leiman, 1957). Another alternative was to use a method of scaling the items that removed individual differences in the use of the item-response categories while retaining, as a separate variable, the mean item response. The details of this method are given in the Appendix.

We used this method of scaling with the five-alternative leisure-time items, the three-alternative vocational items, and the four-alternative talent items. The personality self-ratings were heterogeneous items for which no strong common factor existed, so that such scaling would be inappropriate and unnecessary. Because this scaling procedure effectively eliminated individual differences in item means, these means—the mean expressed interest in the 100 occupational categories, the mean interest in the 120 leisure-time activities, and the mean self-rated degree of the 40 talents—were included with the factor scores as variables.

Factor Analysis

Item responses of 903 twin pairs, concordant for completing the 291 items, were scaled as explained above and then factor analyzed (principal components were extracted and 40 orthogonal factors were subjected to varimax rotation using the Pathmark Factor Analysis System) to produce the 39 interpretable orthogonal factors listed in Table 1. Six of the factors (e.g., Well Adjusted and Irritable or Neurotic) included only talent and self-rating items, although 4 of these 6 (Mental Vigor, Attractive Personality, Hardworking and Productive, and Persuasive and Assertive) had obvious vocational relevance. Eight factors included only leisure items (e.g., Passive Entertainment and Swinger),

Table 1
The 39 Factors Based on 100 Occupational Interest (O) Items, 120 Leisure-Time Interest (L) Items, and 71 Talent (T) Items and Self-Rating (R) Items

Factor	No. items (by type) O	L	R	T	Total no. items	α
Industrial Arts	4	6		4	14	.86
Passive Entertainment		7			7	.62
Physical Appearance	2	1		1	4	.58
Personal Service Work	7				7	.72
Writer	6	1		1	8	.77
Reading		5			5	.73
Blue-Collar Interests	7	2			9	.76
Religious Activities	4	6	1		11	.91
Public Official	6	4	1	2	13	.85
Athletics & Coaching	6	6	1	2	15	.83
Working With Animals	6	3	1	1	11	.86
Gambling	1	6		1	8	.80
Arts & Crafts	5	5	1	1	12	.74
Sewing & Weaving		2		1	3	.80
Well Adjusted			9	2	11	.75
Irritable or Neurotic			3		3	.52
Buying & Selling	6	2		2	10	.73
Working With Food	3	3		2	8	.77
Scientist & Explorer	4	1		1	6	.51
Travel	2	6			8	.68
Home Activities		8			8	.48
Accountant or Numbers Person	6	2			8	.72
Musician or Performing Artist	4	3		2	9	.79
Medical & Dental	6				6	.74
Farmer or Rancher	3				3	.81
Swinger		6			6	.72
Attractive Personality				5	5	.54
Hardworking & Productive			5	3	8	.57
Socializing		7			7	.63
Blood Sports		6			6	.87
Persuasive & Assertive			1	3	4	.62
Mental Vigor			5	2	7	.68
Interpersonal Warmth	1		3	2	6	.68
The Law	4				4	.72
The Military & Police	3				3	.67
Physical Fitness		5		1	6	.55
Wilderness Activities		4			4	.74
Risky Activities	3	2		1	6	.76
Self-Educating		6			6	.51
Unused items	1	5			6	

Note. Factor scores were computed as the sum of the scaled item responses of the items loading most strongly on that factor. Six items having no loadings greater than .29 were discarded.

whereas 5 included only occupational items (e.g., Medical and Dental, Personal Service Work, and the Law). The remaining 20 factors combined occupational and leisure interests with talents or other self-rated attributes.

It should be emphasized that these 39 factors are not offered here as a comprehensive and optimized representation of the structure of the domain of interests. Each factor was scored by summing the scaled item responses of all items having their strongest loading on that factor. Six items having no loadings higher than .29 were not scored. As shown in Table 1, the alpha reliabilities of these factor scales ranged from .48 to .91, and eight of the scales (especially the shorter ones) had alphas lower than .60. Such scales would be psychometrically unsuitable for individual assessment, and if that were our purpose, many of these scales would have to be fleshed out with additional new items, unreliable items would have to be deleted, and the entire analysis would have to be repeated on a new sample, exploring possible oblique solutions. For our purposes, however, as outlined above, this wide range of alpha reliability was desirable because it allowed us to explore the relationship of scale alpha to measures of twin similarity and of the retest stability of these scales.

Superfactors

For each of these 39 variables, plus the three item-response means, we separately computed quadratic regressions on age by sex and constructed norms to permit each variable to be converted to age- and sex-corrected *T*-score values with means of 50 and standard deviations of 10. Because the members of each twin pair were of the same age and sex, this correction was necessary to prevent spurious inflation of the within-pair correlations (see McGue & Bouchard, 1984). These 42 variables, age and sex corrected and in *T*-score form, were intercorrelated over the entire set of 4,014 middle-aged subjects (twins and their spouses or relatives) and subjected to orthogonal factor analysis, yielding the 11 superfactors listed in Table 2. Several component factors (e.g., Mental Vigor, Industrial Arts, and Attractive Personality) had substantial and understandable loadings on more than one superfactor. Superfactor 5 seemed to be related to group solidarity or tribalism, similar perhaps to the basic interpersonal dimension that Wiggins (1991) and others have called *Communion;* however, we labeled this superfactor *Solidarity.* Superfactor 3—which combined mean talent with the factors we called *Well Adjusted, Hardworking and Productive, Mental Vigor,* and *Persuasive and Assertive*—might be identified with Wiggin's second basic dimension, Agency. The Medical and Dental component factor correlated with Scientist and Explorer among male subjects but with Interpersonal Warmth among female subjects, and we therefore scored both a Male Physician and a Female Physician superfactor. We caution once again that these dimensions are not proffered as the definitive structure of the second-order structure of the interest domain, but merely as illustrative superfactors.

Table 2
Superfactors Based on the 39 Interest–Talent Factors

Superfactor	α
1. Intellectual & Educated Writer, Reading, Self-Educating, Public Official, Mental Vigor, Musician or Performing Artist, **Industrial Arts, Blue-Collar Interests, Socializing**	.90
2. Breadth of Interests Travel, Wilderness Activities, Leisure Mean, Vocational Mean, **Home Activities, Passive Entertainment**	.84
3. Self-Esteem Talent Mean, Well Adjusted, Hardworking & Productive, Mental Vigor, Persuasive & Assertive	.71
4. Adventurous Versus Harm-Avoidant Occupations Risky Activities, the Law, the Military & Police, **Working With Food, Personal Service Work**	.88
5. Solidarity Blood Sports, Attractive Personality, Interpersonal Warmth, Public Official, **Physical Fitness**	.65
6. Artificer Versus Athlete Arts & Crafts, Industrial Arts, Sewing & Weaving, **Athletics & Coaching, Physical Fitness**	.82
7. Religious Orientation Versus Sensual Indulgence Religious Activities, **Gambling, Swinger**	.89
8. Personal Attractiveness & Charm Physical Appearance, Attractive Personality	.55
9. Agrarian Activities Working With Animals, Farmer or Rancher, Wilderness Activities	.86
10. Male Physician Medical & Dental, Scientist & Explorer	.69
11. Female Physician Medical & Dental, Interpersonal Warmth	.73

Note. Negatively loaded factors are shown in boldface. Superfactor scores were computed as the sum of the scaled item responses of the positively loaded factors minus the corresponding sum for the negatively loaded factors, if any. Alpha reliabilities were based on these same composite item scores. Vocational Mean is the mean score on the 100 vocational interest items; Leisure Mean is the mean interest in the 120 leisure-time activities; Talent Mean is the average self-rating on the 40 talent items.

Data Analyses

Results of the Single Testing of the Total Sample

Each twin correlation is given below, along with the standard error of the estimate based on Fisher's (1921) *Z* transformation and the number of twin pairs. The mean of 50 or 291 correlations, each of which was based on the total number of twin pairs, is a much more accurate estimate of that sample's mean correlation than was suggested by the standard error.

Items. We obtained scaled responses for the 291 items for 903 pairs of same-sex twins and then corrected them for age and sex. We computed intraclass correlations on the individual items for 512 pairs of MZ twins and 390 pairs of DZ twins. The twin correlations for these single items are plotted in Figure 1; the R_{DZT} values ranged from .00 to .44 (mean $r = .14$, $SE = .05$), and the R_{MZT}s ranged from .11 to .67 (mean $r = .32$, $SE = .04$). The MZA-twin item correlations were also plotted for comparison; they averaged .34 ($SE = .12$), with greater variance because of the smaller sample size.

We next computed individual-item heritabilities, using the Falconer (1960) formula given in the introduction. These 291 individual-item heritabilities ranged from −.04 to .78 (mean $r = .36$, $SE = .127$), slightly higher than the mean R_{MZT}. The variability of the Falconer heritabilities was also considerably greater than it was for the twin correlations.

Factor scores. We derived scores on the 39 factors and the 11

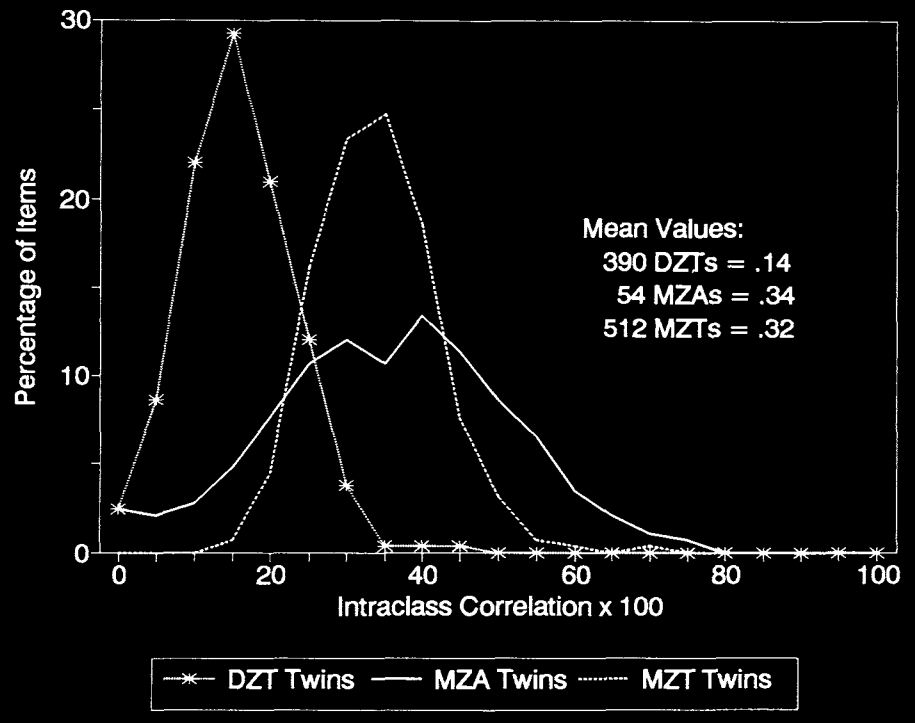

Figure 1. Distributions of intraclass correlations for 291 interest–talent single items administered once to 512 monozygotic twins reared together (MZTs), 54 monozygotic twins reared apart (MZAs), and 390 dyzygotic twins reared together (DZTs). (The sample consisted of pairs of adult twins.)

superfactors by summing the scaled responses to the items loading most strongly on the respective factors. These factor scores, age and sex corrected, were available for 512 pairs of MZ twins and 390 pairs of same-sex DZ twins from the registry. We found the ranges and mean values of the within-pair intraclass correlations to be very similar for men and women. We then recalculated the twin correlations for the sexes combined, after correcting for age and sex. These correlations are plotted in Figure 2. As was true for individual items, Falconer heritabilities were more variable than the twin correlations. Average heritability, estimated from the MZT correlations based on 512 twin pairs, increased from .32 at the item level to .49 (SE = .03) for the 50 factors; the Falconer heritabilities increased correspondingly from .36 to .53 (SE = .117).

The correlations for the 54 pairs of MZA twins, also shown in Figure 2, were, of course, more variable and averaged slightly smaller (mean r = .42, SE = .11) than those for the MZT twins (mean r = .49, SE = .03). However, 47 of the 50 MZT correlations fell within the 95% confidence interval surrounding the corresponding MZA correlations. Because about one third of the MZA twins were reared outside of the United States, it may be that the interest-factor structure for this group was somewhat different than that obtained with the Minnesota-born sample of reared-together twins. In view of the fact that the MZAs were at least as strongly correlated as the MZTs on the individual items, a difference in factor structure might well account for the slightly lower mean MZA factor correlation.

This increase in heritability of factors as compared with items was due to the greater reliability of item aggregates. Although the estimated heritability of some individual items was remarkably high, the common factors underlying the sets of correlated items were, on average, substantially more heritable than were the items individually. Because the factor scales themselves varied widely in reliability, we could quantify this effect by regressing the MZT correlations for the 50 factors on their alpha reliabilities; the regression was linear and the correlation was .60.

The 3-Year Retest Stability of Items and Factor Scales

We obtained 3-year retest stability correlations for 186 of the male twins and 210 of the female twins. Stabilities for the 291 individual items ranged from .32 to .85 (mean r = .57, SE = .03). For the 39 factors, stabilities ranged from .48 to .89 and averaged .74 (SE = .02). The alpha reliabilities for these factors, given in Table 1, were computed using all the data (twins and family members). The alphas were somewhat smaller than the retest stabilities, averaging .71 (SE = .01). We also computed alphas and retest correlations for the 11 superfactors. The superfactors had higher alphas (.77 vs. .71) and were more stable than the component factors (mean r = .79, SE = .02, versus mean r = .74, SE = .01).

For the sexes combined, the magnitude of the MZT-twin correlations (used here as conservative estimates of heritability) for all 50 factors were themselves correlated .86 (SE = .01) with the 3-year retest stability coefficients; that is, the more stable traits yielded higher MZT within-pair similarity. Because the R_{MZA}s were based on a much smaller sample, they correlated

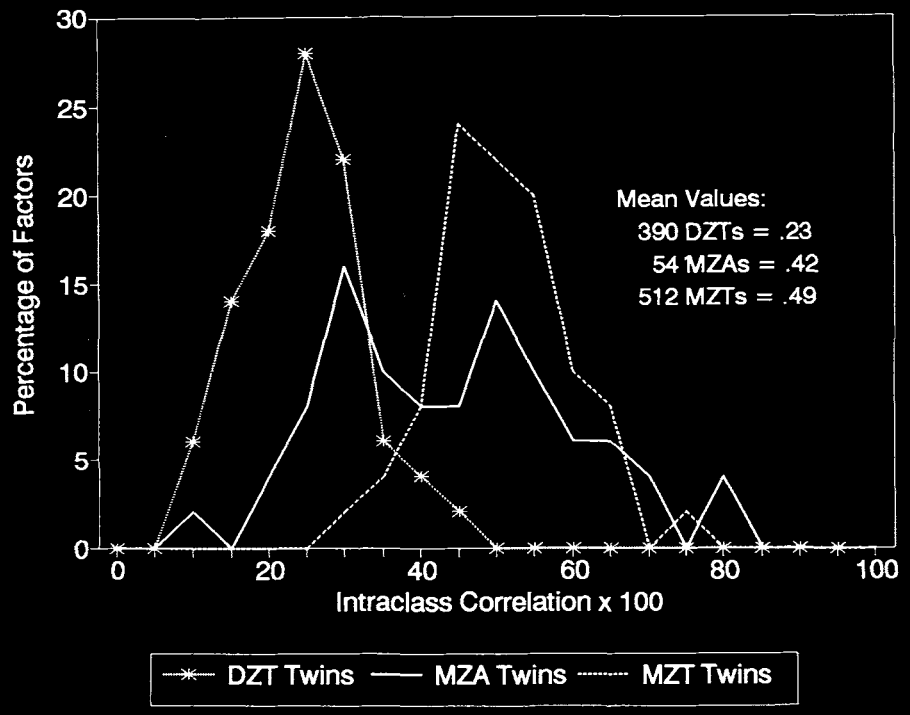

Figure 2. Intraclass correlations for 39 first-order and 11 second-order factor scales derived from the 291 interest–talent items (DZT = dyzygotic and reared together; MZA = monozygotic and reared apart; MZT = monozygotic and reared together.)

less with retest stability (mean r = .59, SE = .09). A similar relationship to retest stability held true at the item level: the correlation between R_{MZT} and retest stability for the 291 individual items was .58 (SE = .03).

Correcting for 3-Year Instability

Items. An estimate of twin similarity corrected for either item or factor instability was provided by the usual formula, retest ratio = R_{MZT}/R_{retest}. If the retest ratio accurately estimates the heritability of the stable component of the trait being measured, then the average retest ratio should approximate the mean heritability for perfectly stable measures as estimated from the regression of R_{MZT} on retest stability. We thus computed retest ratios for the 291 individual items. The mean of these values, along with the mean R_{MZT} for the single testing of the total sample, is given in the first column of data in Table 3. As shown, the mean item heritability estimate (R_{MZT}) increased from .32 (SE = .04; mean R_{MZA} = .34, SE = .12), for a single test administration, to .57 (SE = .03; mean R_{MZA} = .59, SE = .09) when corrected for attenuation because of instability. Moreover, when these retest ratios for the 291 items were plotted against the items' retest stabilities, these disattenuated MZ correlations correlated only .20 (SE = .06) with stability, indicating that the retest ratio provided a good correction for instability of the MZ correlations on items.

Retest factor scores. The average heritabilities for the 39 factor scores and the means of the factor retest ratios are given in column 2 of Table 3. As shown, average factor R_{MZT} (heritability) increased from .48 (SE = .03; mean R_{MZA} = .41, SE = .11) for a single testing to .65 (SE = .03; mean R_{MZA} = .55, SE = .11) when corrected for instability. The mean twin correlations for the 11 superfactor scales, age and sex corrected, for the single

Table 3
Mean Heritability of Interests–Talents as Estimated by Measures That Vary in Adequacy of Content Sampling and in Retest Stability

	Measures: adequacy of content sampling		
Retest: control on transitory errors	Single item[a]	Factor[b]	Superfactor[c]
Heritability estimated from single testing			
R_{MZT}	.32	.48	.53
R_{MZA}	.34	.41	.48
Heritability estimated from the retest ratio			
R_{MZT}	.57	.65	.66
R_{MZA}	.59	.55	.61

Note. MZT correlations, corrected for age and sex, were based on 512 pairs of middle-aged monozygotic twins reared together. MZA values were based on 54 pairs of monozygotic twins reared apart. Retest ratios were the MZA correlations divided by the retest correlations for that item or factor.
[a] Alpha undefined. [b] α = .63. [c] α = .73.

testing of all 512 MZT pairs and the 54 MZA pairs and the mean disattenuated values are given in column 3 of Table 3.

The mean heritability estimate for a single testing increased from .32 for individual items, to .48 for factor scales, to .53 for superfactors. Heritability estimates based on the retest ratio increased from .57 (SE = .03) for individual items to .65 (SE = .03) for factor scales to .66 (SE = .03) for superfactors, as shown in Table 3. However, when the retest ratios of the MZ correlations for the 50 factor scores were plotted against factor stability, the quadratic regression showed considerable residual relationship, r(ratio:stability) = .49 (SE = .09), between the disattenuated correlations and retest stability. A plot of this regression indicated that the MZ retest ratio averaged .52 when the retest correlation was .50, rising to .82 when the stability was 1.00. This suggested that, for factor scores but not for individual items, the retest ratio underestimated the R_{MZT} that would be found with completely stable measures. Thus, the mean R_{MZT} ratios of .65 and .66 (.55 and .61 for R_{MZA}) shown in Table 3 may underestimate the true heritability of the stable components of interest- and talent-factor scores.

The mean disattenuated DZT correlation was .30 (SE = .05) for the 50 factors (mean R_{DZA} = .18, SE = .15), less than half the mean values for MZT and MZA twins (.65, SE = .03, and .56, SE = .09, respectively), suggesting nonadditivity in the genetic components of some of these factors. One example of such an emergenic trait was the Arts and Crafts factor, for which the correlation of MZT was .63 (SE = .03), whereas the DZT correlation was .07 (SE = .05), similar to Moloney et al.'s (1991) finding for the Artistic superfactor in the SVIB and JVIS composite administered to their sample of twins reared apart. Figure 3 is a scatterplot of MZT versus DZT correlations on the 291 individual items, based on one testing of the 512 MZT and 390 DZT pairs. Items plotted above the line, 67% of the total, are those for which the MZT correlation was more than twice the DZT value, suggesting emergenesis for these items. Figure 4 shows a similar scatterplot for the 50 factor scores; this one used the more stable correlations based on the means of two testings of 102 MZT and 96 DZT pairs. As was found for individual items, R_{MZT} was considerably larger than twice the R_{DZT} for a number of the factors. To the extent that stable interests are determined emergenically, they may not run in families and their substantial heritability might not be discovered through adoption studies of the type on which Gati (1991) relied (e.g., Grotevant, Scarr, & Weinberg, 1977).

Discussion

A Plausible Mechanism for Genetic Influence on Interests

Interests are learned traits. If genetic factors contribute to the variance of interests, it must be through the mechanisms of gene–environment interaction and correlation (Plomin et al., 1977; Scarr & McCartney, 1983). A rational, cooperative subject will not express interest in, say, team sports if he or she has never participated in such sports and does not know what they are. A strong, well-coordinated, energetic, adventurous, and competitive child who is exposed to active games and sports while growing up is likely to enjoy and be successful in such activities and to develop an interest in sports. Other traits, such

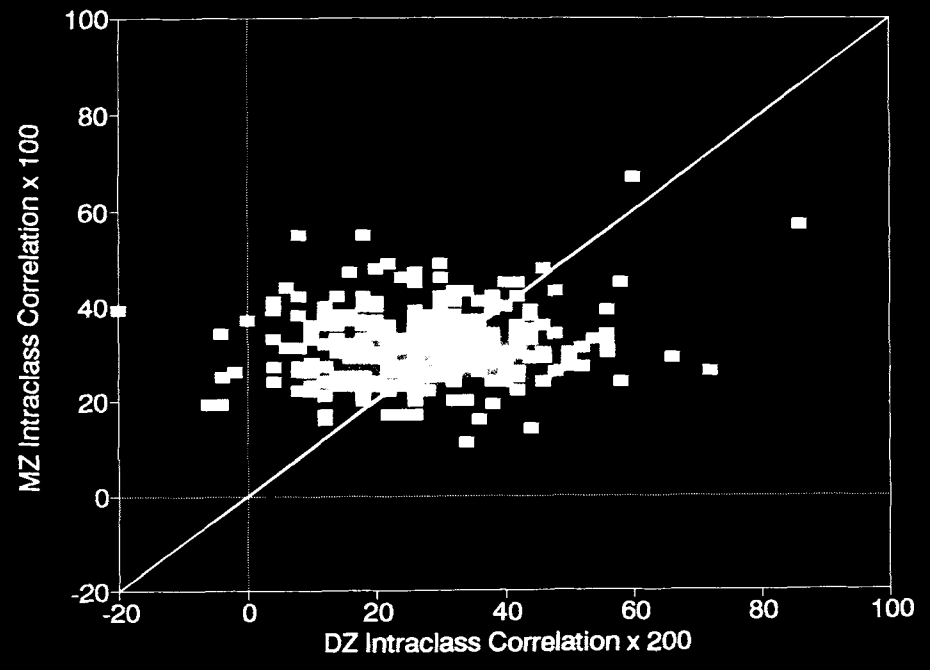

Figure 3. Scatterplot showing the intraclass correlations of 512 monozygotic twin pairs reared together (MZTs) versus the correlations (doubled) of 309 dyzygotic pairs reared together (DZTs) for 291 interest–talent items administered once. (For the 67% of items above the plotted diagonal, the MZ correlation is more than twice as large as the DZ correlation, suggesting a nonadditive, or emergenic, effect.)

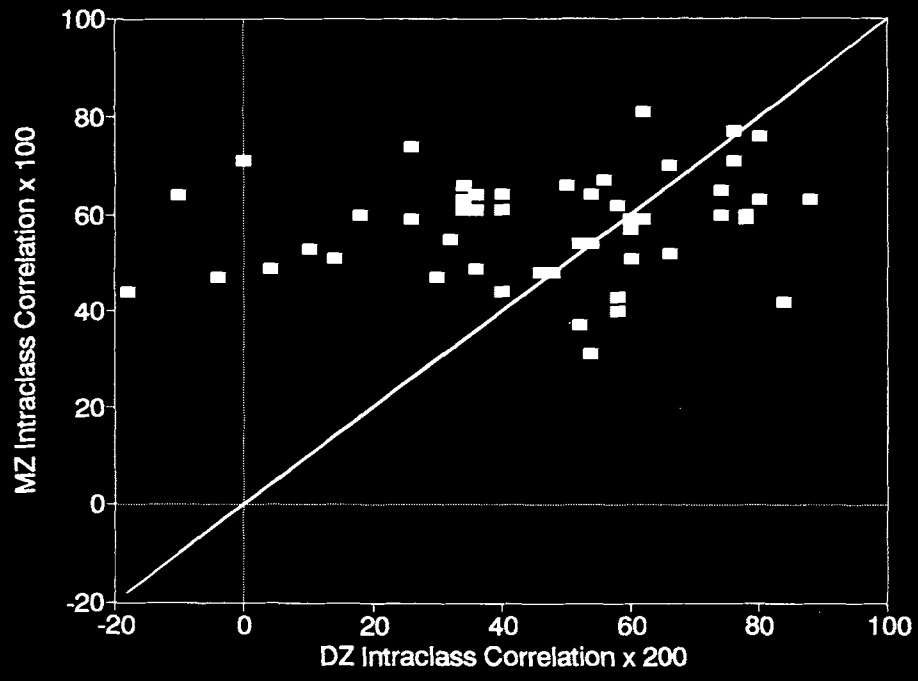

Figure 4. Scatterplot showing the intraclass correlations of 512 monozygotic pairs reared together (MZTs) versus the correlations (doubled) of 309 dyzygotic twin pairs reared together (DZTs) for the 50 factors. (Factors were derived from the 291 interest–talent items and computed from the means of two sets of factor scores obtained from 102 MZT pairs and 96 DZT pairs who were tested twice, 3 years apart.)

as the affinity for tribal activities measured by the Solidarity factor discussed above, may determine whether this interest is stronger for team sports than for individual sports. Some of the attributes listed above such as strong and energetic, obviously have a genetic basis, although it cannot be specified which genes are involved, much less the mechanisms through which these genes create muscle or energy resources. Other attributes, such as adventurous, competitive, and tribal, are themselves psychological traits that might seem even further removed than, say, well coordinated is from the gene level. Yet there is good evidence that personality traits also are strongly influenced genetically (e.g., Bouchard & McGue, 1990; Eaves et al., 1989; Loehlin, 1992; Tellegen et al., 1988).

Therefore, it seems reasonable to suppose that certain precursor traits of physique, aptitude, temperament, and personality, themselves in part genetically determined, in the context of a given "cafeteria of experience," help to determine both (a) which experiences are selected and (b) how the individual reacts to those experiences. An individual whose cafeteria has not provided experience with team sports or foreign travel or computer programming can only imagine what such activities are really like. What is offered in the cafeteria of experience is also influenced, of course, by social convention or stereotyping. If boys are made to think that working with food or fabric is "sissy" and girls are discouraged from learning to use tools, potential latent skills and interests may not be developed. These interests could be said not to be well traited for such people; their opinions, being based on limited and unreliable information, will reflect person factors less and situational factors more, and thus tend to be unstable over time. Interests that lack temporal stability cannot be useful for individual prediction.

It might be supposed that a set of items that are positively correlated in the population, like those that make up the scales of factor-analytically derived interest inventories, must be traited because they seem to measure a single common factor. For example, all of the items referring to foreign travel in the MLIT formed a positive manifold. Yet the 3-year stability of the Travel scale was only .63, compared with .86 for Athletics or .85 for Religious Activities. Most middle-aged Americans have little experience with (especially foreign) travel, compared with their experience in athletic or religious activities. Because the idea of travel is salient in all these items, people are likely to respond to them similarly on any occasion of testing, even though the direction of their response may be determined by ephemeral considerations. When one is ill, fatigued, or frightened, these items might be rated lower than when one is feeling vigorous, hungry for adventure, and bored with the daily grind. A person with experience of foreign travel, however, is likely to have a more well formed and stable sentiment, pro or con, toward such activities than is someone lacking that experience. That is, the traitedness of the interest in foreign travel is likely to increase with one's actual experience with that activity.

It is possible to have definite and stable attitudes toward certain unexperienced activities, based on commonsense inference as to what those activities are like combined with stable self-knowledge. Thus, a shy person may express stable lack of interest in a career as a performer or a politician. Assumptions about how one would enjoy certain vocations are sometimes mistaken, of course; this is the point of vocational counseling.

A person who is fond of children but sentimental and intolerant of stress might naively suppose that he or she would enjoy working as a pediatrician, for example. Thus, some interests can be stable in the absence of direct experience, but not all such interests, although stable, will be veridical predictors.

Conclusions

We are now able to answer the questions set forth at the start of this article. In this large and representative sample of middle-aged, Minnesota-born twins, most of whom have been married and living apart for many years, more than 30% of the variance in occupational and leisure interests can be attributed to genetic factors even at the level of individual test items. When the single-item responses were combined into factor-analytically derived scales, heritabilities based on a single administration averaged .48, whereas the mean for superfactors was .53. In contrast with Gati's (1991) estimate of 5%, about one half of the variance in interest scores was associated with genetic variance. Disattenuated for instability, the mean heritability estimates became .65 for factor scales and .66 for superfactors. Thus, as much as two thirds of the stable variance of recreational and vocational interests was associated with genetic differences among people.

The heritability of a trait is equal to the square root of the correlation between genotype and phenotype. When superfactor scores were aggregated over repeated measurements, so as to estimate each subject's stable mean, our data predicted a mean heritability of .66, which would indicate that these stabilized phenotypes correlated .81 with the underlying genotypes. The mean heritability of single-item responses, nonaggregated, was .32, indicating that the correlation between genotype and a response to a single item at one point in time was .57. As one reviewer pointed out, this is a remarkable finding.

This is not to say, however, that our species has evolved genes patterned after the *Dictionary of Occupational Titles* (U.S. Department of Labor, 1991). Because specific interests are undoubtedly learned, these findings must be interpreted to mean that the experiences people seek, and the effect of those experiences on their developing interests, are influenced by traits of physique, aptitude, and temperament—and perhaps by certain not-yet-identified primitive or primary interests—that are themselves substantially genetically influenced.

Does inclusion of recreational interests and self-assessed talents enhance the measurement of occupational interests? Leisure-interest items relate in sensible ways to vocational-interest items, and moreover, self-rated talents and personal characteristics correlate appropriately with both kinds of interest, as predicted from a model based on gene–environment correlation and interaction. Thus, the Industrial Arts factor, in addition to including interests in the building trades, heavy construction, skilled trades, and craft work, such as furniture or toolmaking, includes recreational interests in making things, repairing cars or boats, remodeling houses, model building, and repairing things and also the talents for carpentry, mechanics, electrical work, and reading maps or plans. This factor had an alpha reliability of .86, a heritability of .58, and a disattenuated heritability of .76.

Do MZT-twin correlations provide good estimates of the heritability of interest–talent factors? At the levels of individual items, factors, or superfactors, the mean Falconer heritabilities were consistently higher than the mean R_{MZT}s, whether computed on a single testing, the mean of two testings, or in terms of the retest ratio. Because the R_{DZT} values were frequently less than half of the R_{MZT}s, presumably because of the effects of nonadditive genetic variance, the Falconer formula tended to overestimate broad heritability, sometimes yielding nonsensical values higher than 1.00. When working with adult twins, the MZT-twin correlation is not only a more reliable estimate of heritability, it is also a more conservative estimate. (One would want to assess DZ twins, in any case, to verify the assumption that shared environmental effects are negligible.)

Do heritability estimates increase with increased stability of the measures on which they are based? Correlations for MZT twins on 50 interest–talent factor scores, based on 512 adult twin pairs, correlated .86 with the 3-year retest stability coefficients of those factors. These heritabilities averaged .48 on the basis of a single test administration but increased to .66 when disattentuated for instability.

As suggested by our model, one important determinant of trait or item stability must be the extent of the respondent's experience with the referent of that trait or item. For example, the leisure-time item "listening to religious music" had a 3-year stability of .74, suggesting that most people had enough experience with this activity to form a stable sentiment for or against it. "Listening to public radio or watching public television," however, had a stability of only .38, suggesting that most respondents did not have sufficient experience with this activity to have a fixed opinion. "Going on a cruise ship to interesting places," similarly, although unstable (.42) in this population, would presumably show higher stability among people who had actually taken a cruise.

This is not to suggest, however, that interest items will always lack validity unless the specific activity has been experienced firsthand. The vocational items "novelist, script writer, playwright"; "veterinarian, pet animals"; and "astronaut, test pilot, undersea explorer, mountain climber" were each relatively stable, presumably because most people know whether they possess any writing talent, or like animals, or have the stomach for dangerous work. "Watch boxing, live or on TV" had a 3-year stability of .82, although few respondents had seen boxing live and this sport was no longer a weekly feature on network television. It seems likely that temperamental characteristics, which are stable, may largely determine one's attitude toward watching boxers trying to hurt one another. But "television crew: producer, camera, or audio person;" "real estate investor: buying, selling property;" and "foreign correspondent, foreign service officer, etc." describe activities for which human evolution has not specifically prepared us and in which people can less easily picture themselves; this may be why these items were relatively unstable. The mean of the talent items was more stable (.78) than the means of either the occupational or the recreational items (both .66), reflecting the fact that people know themselves rather better than they know the broad worlds of work or of play.

In the interest–talent domain, is the genetic influence stronger for specific activities or talents (i.e., items) or for the more general dispositions responsible for the intercorrelation within item

clusters? The heritabilities for MZT twins of 50 interest–talent factor scores correlated .60 with the alpha reliability of the factor scales. Mean heritabilities increased from .32 for items, to .48 for factors, to .53 for superfactors; the corresponding disattenuated estimates were .57, .65, and .66, respectively. It thus appears that specific interests are less heritable than are the more general underlying factors. For example, different unshared experiences may determine the specific ways in which a strong interest in Working With Animals, one of our 39 factors, manifests itself. Among the MZA twins studied by Bouchard et al. (1990) were two women who were both "dog people," but one exhibited her purebred dogs in conformation shows, whereas the other taught classes in obedience training. Had these women been reared together, they might have expressed their interest more concordantly (R_{MZT} on this factor was .62, R_{MZA} was .50).

Yet, other MZA pairs discovered, when they first met as adults, that they both enjoyed working in their basement carpentry shops, or were both amateur gunsmiths, or were both captains of volunteer fire departments—expressions of similar and quite specific interests. One set of female triplets grew up thinking they were trizygotic until, while in college, they enrolled in one of our studies and blood testing revealed that they had identical genomes. Ten years later, each of these young women had acquired master's degrees—in nursing, special education, and social work, respectively—and were employed in those three different helping professions. A pair of MZ men, however, studied at about the same time, took quite different paths: One became a physician, and the other, after 6 years as a medical researcher, became a graphic designer. (The physician now says that, if he could start again, he would be an artist.)

Choices in the world of work are more constrained than are choices of recreational activities, so one cannot expect MZ twins to have occupations as similar as their leisure-time activities tend to be. Job choices are no doubt especially limited for women; in a survey of more than 500 twins, Lykken and Tellegen (in press) found that 28% of female MZ twins said they would dislike having their cotwin's job, compared with only 10% of male MZ twins; it may well be that the female cotwins themselves were unenthusiastic about the jobs available to them. Nevertheless, 42% of the female MZ twins and 64% of the male MZ twins expressed a positive attitude (rather than dislike or neutrality) toward their cotwin's choice of employment.

Is there evidence for emergenesis (nonadditive genetic effects) in the interest–talent domain? For twins reared together, any lasting effects of being reared in a common family environment will tend to make the DZT correlation greater than half of the MZT correlation. Nonadditive genetic effects tend in the opposite direction, in which R_{DZT} is less than half of R_{MZT}. We found that, for 67% of our 291 individual items and 62% of our 50 interest–talent factors, R_{MZT} exceeded twice the R_{DZT}, suggesting that emergenesis plays a significant role in the interest–talent domain. For a few traits, such as the Arts and Crafts factor discussed earlier, the MZT correlation was substantial, whereas the similarity of DZT twins (and, presumably, of other first-degree relatives) was essentially zero. For strongly emergenic traits such as this one, the important role of genetic influence will not be discovered in family studies that do not include monozygotic twins.

These findings extend the already large body of evidence that indicates the important influence of genetic factors on virtually all traits that are of interest to applied psychologists (Bouchard, Arvey, Keller, & Segal, 1992). More important, however, we hope that these results will stimulate further research on the problem of how interests develop through gene–environment interaction and correlation and on how and to what extent interests can be redirected or enhanced by intervention during development.

References

Bouchard, T. J., Jr., Arvey, R. D., Keller, L. M., & Segal, N. L. (1992). Genetic influences on job satisfaction: A reply to Cropanzano and James. *Journal of Applied Psychology, 77,* 89–93.

Bouchard, T. J., Jr., Lykken, D. T., McGue, M., Segal, N. L., & Tellegen, A. (1990). Sources of human psychological differences: The Minnesota Study of Twins Reared Apart. *Science, 250,* 223–228.

Bouchard, T. J., Jr., Lykken, D., McGue, M., & Tellegen, A. (1992, April). Genes, drives, environment and experience: EPD theory—revised. Paper presented at a symposium in honor of Julian C. Stanley, San Francisco.

Bouchard, T. J., Jr., & McGue, M. (1990). Genetic and rearing environmental influences on adult personality: An analysis of adopted twins reared apart. *Journal of Personality, 58,* 263–292.

DeNisi, A. S., & Shaw, J. B. (1977). Investigation of the uses of self-reports of abilities. *Journal of Applied Psychology, 62,* 641–644.

Eaves, L. J., Eysenck, H. J., & Martin, N. G. (1989). *Genes, culture, and personality.* San Diego, CA: Academic Press.

Falconer, D. S. (1960). *Introduction to quantitative genetics.* New York: Ronald Press.

Fisher, R. A. (1921). On the probable error of a coefficient of correlation deduced from a small sample. *Metron, 1,* 3–7.

Gati, I. (1991). The structure of vocational interests. *Psychological Bulletin, 109,* 309–324.

Grotevant, H. D., Scarr, S., & Weinberg, R. A. (1977). Patterns of interest similarity in adoptive and biological families. *Journal of Personality and Social Psychology, 33,* 667–676.

Li, C. C. (1987). A genetical model for emergenesis. *American Journal of Human Genetics, 41,* 517–523.

Loehlin, J. C. (1992). *Genes and environment in personality development.* Newbury Park, CA: Sage.

Loehlin, J. C., & Nichols, R. C. (1976). *Heredity, environment, and personality.* Austin: University of Texas Press.

Lykken, D. T. (1968). Statistical significance in psychological research. *Psychological Bulletin, 70,* 151–159.

Lykken, D. T. (1982). Research with twins: The concept of emergenesis. *Psychophysiology, 19,* 361–373.

Lykken, D. T., Bouchard, T. J., Jr., McGue, M., & Tellegen, A. (1990). The Minnesota Twin Family Registry: Some initial findings. *Acta Geneticae Medicae et Gemmellologiae, 39,* 35–70.

Lykken, D. T., Geisser, S., & Tellegen, A. (1981). *Heritability estimates from twin studies: The efficiency of the MZA design.* Unpublished manuscript, University of Minnesota, Department of Psychology, Minneapolis.

Lykken, D. T., Iacono, W. G., Haroian, K., McGue, M., & Bouchard, T. (1988). Habituation of the SCR to strong stimuli: A twin study. *Psychophysiology, 25,* 4–15.

Lykken, D. T., McGue, M., Tellegen, A., & Bouchard, T. J., Jr. (1992). Emergenesis: Genetic traits that may not run in families. *American Psychologist, 47,* 1565–1577.

Lykken, D. T., & Tellegen, A. (in press). The capriciousness of human mate selection: The role of infatuation. *Journal of Personality and Social Psychology.*

McCartney, K., Harris, M. J., & Bernieri, F. (1990). Growing up and growing apart: A developmental meta-analysis of twin studies. *Psychological Bulletin, 107,* 226–237.

McGue, M., Bacon, S., & Lykken, D. T. (1993). Personality stability and change in early adulthood: A behavioral genetic analysis. *Developmental Psychology, 29,* 96–109.

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

Moloney, D. P., Bouchard, T. J., Jr., & Segal, N. L. (1991). A genetic and environmental analysis of the vocational interests of monozygotic and dizygotic twins reared apart. *Journal of Vocational Behavior, 39,* 76–109.

Nichols, R. C. (1978). Twin studies of ability, personality, and interests. *Homo, 29,* 158–173.

Pedersen, N. L., Plomin, R., McClearn, G. E., & Friberg, L. (1988). Neuroticism, extraversion, and related traits in adult twins reared apart and reared together. *Journal of Personality and Social Psychology, 55,* 950–957.

Pedersen, N. L., Plomin, R., Nesselroade, J., & McClearn, G. (1992). A quantitative genetic analysis of cognitive abilities during the second half of the life span. *Psychological Science, 3,* 346–353.

Plomin, R., & Daniels, D. (1986). Why are children in the same family so different from one another? *Behavioral and Brain Sciences, 10,* 1–16.

Plomin, R., DeFries, J. C., & Loehlin, J. C. (1977). Genotype-environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin, 84,* 309–322.

Roberts, C. A., & Johansson, C. B. (1974). The inheritance of cognitive interest styles among twins. *Journal of Vocational Behavior, 4,* 237–243.

Scarr, S. (1992). Developmental theories for the 1990s: Developmental and individual differences. *Child Development, 63,* 1–19.

Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype-environment effects. *Child Development, 54,* 424–435.

Schmid, J., & Leiman, J. M. (1957). The development of hierarchical factor solutions. *Psychometrika, 22,* 53–61.

Tellegen, A., Lykken, D. T., Bouchard, T. J., Jr., Wilcox, K., Segal, N., & Rich, S. (1988). Personality similarity in twins reared apart and together. *Journal of Personality and Social Psychology, 54,* 1031–1039.

Tellegen, A., & Waller, N. (in press). Exploring personality through test construction: Development of the Multidimensional Personality Questionnaire. In S. R. Briggs & J. M. Cheek (Eds.), *Personality measures: Development and evaluation* (Vol. 1). Greenwich, CT: JAI Press.

U.S. Department of Labor. (1991). *Dictionary of occupational titles* (4th rev. ed.). Washington, DC: U.S. Government Printing Office.

Vandenberg, S. G., & Stafford, P. E. (1967). Hereditary influences on vocational preferences as shown by scores of twins on the Minnesota Vocational Interest Inventory. *Journal of Applied Psychology, 51,* 17–19.

Waller, N. G., Kojetin, B. A., Bouchard, T. J., Jr., Lykken, D. T., & Tellegen, A. (1990). Genetic and environmental influences on religious interests, attitudes and values: A study of twins reared apart and together. *Psychological Science, 1,* 1–5.

Waller, N. G., Lykken, D. T., & Tellegen, A. (in press). Occupational interests, leisure time interests, and personality: Three domains or one? Findings from the Minnesota Twin Registry. In R. V. Dawis & D. Lubinski (Eds.), *Assessing individual differences in human behavior: New methods, concepts and findings.* Minneapolis: University of Minnesota Press.

Wiggins, J. S. (1991). Agency and communion as conceptual coordinates for the understanding and measurement of interpersonal behavior. In D. Cicchetti & W. M. Grove (Eds.), *Thinking clearly about psychology: Essays in honor of Paul E. Meehl: Vol. 1. Matters of public interest; Vol. 2. Personality and psychopathology* (pp. 89–113). Minneapolis: University of Minnesota Press.

Appendix

Method of Item Scaling

The Likert-type item responses to the interest and talent inventories were scaled to remove individual differences in the use of the several response alternatives. For example, the Minnesota Leisure-Time Interest Test was scaled by first counting the frequency with which the respondent used each of the five alternatives. An enthusiastic respondent might choose Alternatives 4 and 5 twice as often as Alternatives 1 and 2, yielding a distribution of choices skewed to the left. Someone with few interests would show a distribution skewed to the right. A cautious subject might avoid Alternatives 1 and 5, whereas a more positive person might avoid the intermediate alternatives. The scaling objective was to select a new set of scale values for each respondent (values to be chosen for convenience between 0 and 1 rather than from 1 to 5) that would rectangularize that person's distribution of choices. A subject ("Smith") who used each alternative equally (120/5 = 24 times), thus maximizing his or her discrimination among items, would be assigned scale values of .1, .3, .5, .7, and .9. The value of .3 for Alternative 2 is the midpoint of the interval, from .2 to .4, over which Smith's 24 choices of Alternative 2 are plotted in the distribution (histogram) of choices; that histogram would be rectangular for this individual. This scale value of .3 can be interpreted to mean that, for Smith, a choice of Alternative 2 expresses an interest which is, on the average, greater than 30% of all the choices Smith made.

Someone whose distribution of choices is 5, 10, 15, 50, 40, on the other hand, would be assigned (by the method described below) scale values of .02, .08, .19, .46, and .83. By widening the distances between scale values on the right and narrowing those on the left, the histogram of choices plotted on these values becomes rectangular. Because this person ("Jones") often chooses Alternative 4, *frequently,* each such choice is given less weight (.46), rather than the .70 assigned to Alternative 4 for Smith. If Jones chose *frequently* 50 times out of 120, any one of these choices would indicate less relative enthusiasm, greater than only 46% of Jones's choices on average, than it would have expressed for Smith, for whom one such choice would express an interest greater on average than 70% of all choices. Because Jones seldom expresses low interest, when he or she does indicate disinterest, that choice is given greater weight by assigning a scale value further from the mean, which would now be fixed at .50 for all respondents, that is, by giving Jones a scale value of .02 instead of the .10 assigned for Smith.

Computing these individualized scale values involved the following steps: First, the scale value for the lowest, or *never,* alternative is set equal to $(K1/2)/N$, where $K1$ is the number of times that the respondent used the *never* alternative and N is the total number of items (120, in this case). The scale value for *seldom* is set at $[K1 + (K2/2)]/120$, where $K2$ is the frequency with which *seldom* was chosen. The value for *sometimes,* the third alternative, is set at $[K1 + K2 + (K3/2)]/120$, and so on. The ipsatized scores thus derived, when multiplied by 100, can be interpreted as intraindividual percentile values.

The items of the self-rating inventory, unlike the interest and the talent items, did not share a common factor and did not require ipsatized scaling. Instead, the five alternatives of the rating items were assigned scale values of .05, .33, .50, .67, and .95 to reflect the instructions given to the subjects on the inventory form (see main text).

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