GENETIC FACTORS IN ACTIVITY MOTIVATION

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A study of 61 pairs of identical (MZ) and fraternal (DZ) grade-school twin girls found moderate genetic contributions to individual differences in several aspects of activity motivation: reaction time, variety of activity, anxiety, and impatience. Activity motivation was defined by empirical clusters of related measures including ratings, experimental tasks, and interviews. Intraclass correlation coefficients for the MZ and DZ groups were compared, and heritability estimates were computed for every measure. Possible biases in twin research were examined with special emphasis on the environmental similarity of MZ and DZ co-twins.

It is well known that single genes can have deleterious effects on the whole behavior pattern of an individual, as in Huntington's chorea, PKU, and microcephaly. The presence of such a gene removes an individual from the normal range of variation in the larger population. It is less well established that polygenes affect individual differences in behavior

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within the normal range of variation. One quantitative approach to the study of genetic effects on individual differences is the human-twin study.

The present study focuses on one of the basic aspects of human motivation, activity level. Within the normal range of activity levels there are large, persistent individual differences in how much activity per se is initiated, how rapidly or slowly, how often, with how much vigor or apathy, with how much nervous activity or relaxation, and with how much patience or impatience.

Individual differences in motivation may be in part genetically determined, as Hayes (1962) has suggested for his "experience-producing drives." Activity motivation may be influenced more than most other motives by hereditary components. Evidence from phylogenetic studies indicates that some species display far more motor activity than others (mice vs. pigs, for example) and that within a species some strains show five times as much gross motor activity as others (Fuller & Thompson, 1960; Montgomery, 1952; Scott & Charles, 1954).

Human infants also show great individual differences in activity level which tend to persist into adolescence (Kagan & Moss, 1962; Neilon, 1948). Tuddenham's (1959) follow-up of the California Adolescent Growth Study reports persistent similarities in activity levels from adolescence into adulthood over a 20-year period. The phylogenetic and ontogenetic findings suggest that individual differences in activity level may have some hereditary basis.

The term "motivation" was defined as persistent and recurring states of arousal leading to interactions with the environment, which in turn affect the arousal state of the organism. "Activity motivation" has no concise definition in the literature (Cromwell, Baumeister, & Hawkins, 1963), and the term has been used in the service of a broad range of purposes. For this research, empirical clusters of measures, including reaction times, preference for physical activity, anxiety, and impatience, were named and treated as aspects of activity motivation.

To assess genetic contributions to individual differences in activity motivation, the classic twin study method was chosen. Although several motives were investigated, only those findings related to activity are reported here.

METHOD

Subjects

Sixty-one pairs of identical (MZ) and fraternal (DZ) white twin girls between the ages of 6 and 10 in the Boston area were tested and extensively blood-grouped. The final sample contained 28 pairs of DZ twins and 24 pairs of MZ twins whose zygosity was established at or beyond the .95

level of probability. The girls were representative of the Boston metropolitan area in social class, religious, and ethnic backgrounds. They were drawn by area sample from a larger group of twins who volunteered for the Forsyth study in exchange for free dental care. The present sample included 20 per cent of all girl-girl twin pairs of the 6–10 age group in the Boston area, as estimated from the frequency of twins in the total white U.S. population (Allen, 1955; Karn, 1954). Every family contacted agreed to be tested, so that the sample can be considered representative of the larger Forsyth group and of the twins in the Boston area. Since the motivational measures administered have no connection with twinness per se, the findings may be generalized to girls in the Boston area. It is unlikely that the findings should be generalized to boys, nonwhite groups, or to widely differing ethnic populations in other areas of the country.

The mean age of the twins is 97 months, and their mean IQ is 100.4 ($\sigma = 18.5$), estimated by the Goodenough drawings (1926). The modal occupational status of the fathers is skilled worker, followed by lower-white-collar and semiskilled laborer. There are no differences between the identical and fraternal pairs in background, age, and intelligence.

Procedure

Before the zygosity diagnosis was known, the twins and their mothers were tested in their homes by two *E*'s, each of whom administered one set of tasks to both Ss. The two task sets were alternated from day to day, so that each *E* administered each task set to about half of the pairs. At the beginning of the testing session, the author interviewed the mother while the other *E* set up the equipment and entertained the children in another room. The testing session lasted approximately 1¼ hours during which time interviews, standard tests, and experimental games were given. Independent ratings of the twins' behavior by the *E*s were completed immediately after every home visit, and background interviews were conducted with the mothers at a later date by telephone.

Tests

The measures of activity motivation were obtained from two experimental games, an interview with the children, and three sets of ratings.

The Toys game was adapted from a procedure used by Smock and Holt (1962) to measure curiosity. Nine toys, selected for interest, were presented to the Ss, who were asked to choose the toy they would most like to play with after the testing session. After the first decision, the Ss were asked to choose the next best toy, the third best, and so forth, until all of the toys had been ranked in this way. The time required for the Ss to choose each toy yielded a total time score and a time range. A second part of the Toys game involved five trials of choosing between a hidden toy

and one the Ss had seen before it was placed in a box identical to the one in which the hidden toy was located. The hidden and visible toys were chosen according to a prearranged pairing of the ranks the Ss had just assigned to the toys; for example, the first toys hidden were those ranked fourth, and the first ones seen were ranked fifth by the Ss. The time required to choose between the hidden and seen toys was recorded for all five trials. The three reaction times were included to measure how rapidly and how variably the Ss preferred to react to choice situations.

The Slides game used Berlyne's (1960) curiosity stimuli, photographed and mounted as black and white slides. A slide viewer with a mirror at the back projected the stimuli onto a 6 × 6-inch screen on the table in front of the Ss. The light in the projector was regulated by an off-on switch which the Ss were instructed to use. Connected to the switch was a clutch-operated timer that recorded how long the Ss viewed each slide. The Ss were instructed to view the slides for as long or as short a time as they wished, since we wanted to know only if they found the pictures interesting. When they had viewed one slide as long as they wished, the Ss were told to turn off the light, so that *E* could present another slide. The slides were presented in the same order to all of the Ss. The total viewing time and the time range were considered measures of preferred reaction time to new stimuli and variability of performance.

The Activity interview, composed for this study, was designed to discover how many different activities the Ss like and how motorically active or passive their favorite games were. To begin, *E* said, "We're interested in finding out what girls your age like to do. What kinds of activities do you like best?" After recording the initial response, *E* probed for specific games and pastimes which Ss preferred in different contexts, such as recess time in school, weekends, time spent with their co-twins, with girls friends, and so forth. The questionnaire has a prescribed set of open-ended questions to test the variety of activities and the motor-activity dimension. For the total different-activities score, every activity and variant of it was counted once (e.g., jump rope and Chinese jump rope were both counted). To score active versus sedentary games, the criteria were gross movement and/or played primarily out-of-doors versus seated and/or played primarily indoors. The interscorer reliabilities were .92 (Pearson r) for total different activities and .95 for active versus sedentary games.

The Adjective Check List (Gough, 1960) consists of 300 adjectives yielding 26 scales. The mothers were asked to complete two checklists, one for each twin, during the testing session with the twins. They were told to read the adjectives rapidly and to check those which best described each twin. They were given two answer forms so that they could not easily compare their responses. The scales of interest for activity motivation concerned self-control, nervousness, and anxiety, which were theoretically and empirically related to other measures of motor activity.

The Observer ratings, completed independently by the two *Es*, were based on the Fels Child Behavior Scales (Richards & Simons, 1941) and adapted for brief contact with children. In addition, new scales were created to measure vigor, tension, and squirming. Although the two *Es* never saw the Ss, under the same circumstances or at the same time, the interobserver agreement was fairly good, with correlations ranging from .75 for apprehension to .55 for vigor.

Statistical Methods

All of the responses were subjected to two analyses: a factor analysis of the intercorrelations among the measures and the calculation of intraclass correlation coefficients for MZ and DZ groups. The factors analysis indicated the relations among the measures of activity motivation for the whole group of children. The intraclass correlations indicated how closely the two members of a twin pair resembled each other as compared to the variances between pairs for every variable. The intraclass r is a one-way analysis of variance resulting in an F ratio between the within-pair variance and the between-pair variance.

$$r_i = \sigma_b^2 - \sigma_w^2/\sigma_b^2 + \sigma_w^2,$$

where σ_b^2 = variance (mean square estimate) between pairs; and σ_w^2 = variance within pairs.

The intraclass coefficient is interpreted as the proportion of total variance which arises from the similarities between members of a twin pair. If co-twins always receive the same score, $r_i = 1.00$. If they resemble each other no more frequently than random individuals, $r_i = 0.00$. The level of statistical significance of r_i is the same as the F ratio computed from the same mean squares (Fuller & Thompson, 1960).

To test the hypothesis that a group of identical co-twins are significantly more similar to each other than fraternal co-twins for a particular characteristic, the two r_i's are converted to Fisher's z and compared. Any excess correlation for MZ pairs is considered genetically determined if the environments within MZ and DZ pairs are approximately alike.

Objections to the twin method often center on the supposedly greater similarity with which MZ co-twins are treated. Thus, when parents are correct about their twins' zygosity, two factors are confounded: (*a*) the greater genetic similarity of MZ twins, with accompanying physical, intellectual, and personal similarities; and (*b*) the greater similarity of parental treatment, which might create additional similarities. The latter, environmentally created similarities, would bias the results in favor of high genetic estimates.

Fortunately for twin research, not all parents are as aware of zygosity differences as critics believe. In this study, 11 of the mothers were wrong

about their own twins' zygosity. Seven mothers of DZ pairs believed them to be MZ, and four mothers of MZ pairs believed them to be DZ.

An examination of the Adjective Checklist ratings, assessments of similarity between their twins, and stated child-rearing practices of the mothers who were wrong permitted a separation of the two confounding factors. A comparison of the ratings by mothers who were wrong about zygosity with those who were correct had two possible outcomes. If the mothers of mistaken pairs rated their twins like correctly identified pairs of the same blood-group zygosity, then they were probably responding to the genetic similarity of the twins and not imposing additional similarities based on their beliefs about zygosity. If, however, the mothers of mistaken pairs rated them like correctly identified pairs of the other zygosity, their treatment of the twins would probably bias the results by adding environmental variance to the similarities and differences between co-twins. Briefly, if MZ pairs, thought to be DZ, were rated like other MZ pairs, the mothers were probably not creating additional similarities by their treatment of the children. But if MZ pairs, thought to be DZ, were rated like other DZ pairs, then the mothers were responding to their beliefs about the twins and probably biasing the results. Similar predictions apply to DZ twins whose mothers believed them to be MZ twins.

A comparison of the incorrectly identified MZ and DZ pairs showed no significant differences for Adjective Check List ratings, evaluations of similarity, or child-rearing practices between the two groups, but the mothers of MZ pairs, who believed them to be DZ, said their twins were slightly more similar to each other and dressed them alike somewhat more often than the mothers who mistook their DZ pairs for MZ. Despite the mothers' incorrect beliefs about zygosity, these pairs were rated and treated more like other pairs of their actual zygosity. The Vineland Social Maturity Scale (Doll, 1947) showed that mothers expected similar levels of responsibility from and granted similar independence to their twins on the basis of the twins' actual zygosity rather than their beliefs about zygosity. Thus, MZ twins, mistaken for DZ, are treated more alike than DZ twins thought to be MZ. Actual MZ twins have significantly more similar Vineland scores in the total sample and tend to have more similar scores among the mistaken pairs. Although the equivalence of environments for MZ and DZ pairs cannot be proved, some of the more obvious sources of bias can be eliminated by this analysis. From the evidence, the mothers tended to respond to the genetic similarities and differences of their twins, regardless of whether they believed the twins should or should not resemble each other. For a more complete discussion see Scarr (1966).

Another argument against the value of twin studies concerns possible variances caused by differences in intrauterine and birth experiences. Allen (1965) and Price (1950) suspected that some variance in twin studies may be accounted for by differences in antenatal nourishment,

especially in monochorial MZ twins. If this bias exists, it reduces rather than raises genetic estimates because it introduces environmental differences between genetically identical twins. Differences in birth weight of co-twins are thought to influence later development; in this study, however, there were no differences between the MZ and DZ groups in co-twins' birth weight, and birth weight failed to correlate above .20 with any other variable.

The comparison of the intraclass correlation coefficients for MZ and DZ groups is a minimal estimate of genetic contributions to behavior in a population whose MZ and DZ co-twin environments are approximately equivalent.

The Heritability Statistic

The intraclass r_i is used to compute Holzinger's H' or heritability statistic, which estimates the percentage of within-family variance attributable to heredity by comparing the within-pair variance for MZ twins with the variance for DZ twins.

$$H' = \sigma_{DZ}^2 - \sigma_{MZ}^2/\sigma_{DZ}^2.$$

H' is an underestimate of heritability since it compares genetically identical pairs with pairs whose genetic communality is about 50 per cent instead of zero. It should be noted that heritability is a characteristic of the population and not of the trait, and that H' estimates may vary among populations.

RESULTS

The intercorrelations of the measures of activity motivation yielded five independent dimensions: reaction times, number of activities, percentage of active games, anxiety, and patience. Several of the Observer ratings which correlated in the clusters had to be eliminated because they were shown to be biased in favor of the genetic hypothesis. An analysis of the ratings for ten pairs of twins whose zygosity was mistaken by the *Es* showed that twins erroneously thought to be identicals were rated like real identicals and erroneously diagnosed fraternals like real fraternals on several scales. These ratings were more sensitive to belief in zygosity than to actual zygosity. The Observer ratings of apprehension and patience were retained because they were only slightly biased and had higher reliabilities than the others. Table 1 gives the intraclass correlations and heritability values for the measures from each of the five clusters.

Identical twins had higher intraclass correlations for all five measures of preferred reaction time. The MZ coefficients ranged from .49 for the Slides total time to .27 for the Slides time range, with the Toys r_i's falling between. The correlations for preferred reaction time were remarkably consistent: all of the MZ coefficients at least approached significance; all

TABLE 1

INTRACLASS CORRELATIONS OF MEASURES OF ACTIVITY MOTIVATION FOR MZ AND DZ TWINS

MEASURES	MZ		DZ		DIFFERENCES (r_i MZ and r_i DZ)		
	r_i	p	r_i	p	Z	p	H'
Preferred reaction times:							
Toys total time	.34	...	.04	...	1.05	...	.31
Toys time range	.39	.05	.05	...	1.36	.08	.36
Toys hide-see total	.31	...	−.08	...	1.34	.09	.36
Slides total time	.49	.01	.33	...	0.64	...	.24
Slides time range	.27	...	.02	...	0.86	...	.26
Total different activities	.62	.01	.37	...	1.12	...	.40
Percentage active games	.23	...	.23	...	0.00	...	.00
Anxiety:							
Observer rating (apprehensive)	.88	.001	.28	...	3.63	.001	.83
ACL available anxiety	.56	.01	.03	...	2.01	.02	.55
(−) *n* affiliation	.83	.001	.56	.01	1.85	.03	.61
(−) *n* heterosexuality	.57	.01	.54	.01	0.15	...	.07
(−) *n* nurturance	.55	.01	.50	.01	0.23	...	.10
n succorance	−.16	...	−.02	...	0.47	...	...
Patience:							
Observer rating (patience)	.81	.001	.70	.001	0.87	...	.48
ACL self control	.51	.01	.31	...	0.81	...	.29
(−) *n* exhibition	.39	.05	.09	...	1.07	...	.33
(−) *n* autonomy	.40	.05	.11	...	1.05	...	.33
(−) *n* aggression	.35	...	−.08	...	1.49	.07	.40
n endurance	.10	...	.11	...	0.01	...	.00
n abasement	.00	...	.00	...	0.00	...	.00
n deference	.19	...	.02	...	0.57	...	.17

but one of the DZ coefficients were not significant. The estimates of heritability (H') indicated moderate heritability for all preferred reaction-time measures.

The intraclass coefficients for total different activities were considerably higher for MZ than for DZ twins. The heritability estimate was 40 per cent, suggesting that variation in the *number* of activities in which a child engaged was determined in part by genetic factors. The particular *kinds* of games, such as active or sedentary ones, however, were not affected at all by genetics. Nearly all of the girls said that jump rope (an active game) was one of their favorites, regardless of their preference for fast or slow reaction times and many or few total activities. The percentage of active games in the total number of activities tended to be similar for both MZ and DZ twins, and the heritability was zero.

Ratings of anxiety, and its correlates, by the *Es* and the mothers indicated that individual differences in anxiety have a firm genetic basis. The ratings of apprehension and available anxiety had high heritabilities as did a negatively related scale, *n* affiliation. The other scales suggest that al-

though *n* heterosexuality, *n* nurturance, and *n* succorance were related to anxiety or the lack of it, they were largely learned characteristics in this population.

Patience, self-control, *n* exhibition, *n* autonomy, and *n* aggression had moderate heritabilities. This cluster of characteristics described a patience-mildness versus impatience-aggression dimension with higher MZ than DZ intraclass correlations. The other characteristics which correlated with the cluster failed to show any similarities between MZ and DZ co-twins, so that heritability was approximately zero for endurance, abasement, and deference.

DISCUSSION

The common characteristic of measures of activity motivation with moderate genetic contributions is their nonspecific quality. They are orientations toward specific behaviors but are not themselves specific.

The generalized factor of preferred reaction time has moderate heritability in this population. Preferred decision time was shown to have genetic influence in both the Toys and Slides tasks, and the levels of heritability are approximately the same for all five measures. The heritability of preferred reaction time is supported by the earlier work of Frischeisen-Kohler, who found that MZ twins are more similar than DZ twins in preferred speed of tapping and preferred metronomic speed. Other familiar data support the twin evidence: if parents preferred quick reaction times, then only 4 per cent of the children preferred slow; if the parents preferred slow times, then 71 per cent of the children also preferred slow times (Fuller & Thompson, 1960). A slightly different experiment by Newman, Freeman, and Holzinger (1937) yielded results in the same direction. In a recent study of reaction times, Vandenberg (1962) included ten different measures, eight of which showed significantly greater similarity for MZ twins. Freedman (1963) found that infant MZ twins performed very similarly on the Bayley Mental and Motor scales, while the DZ twins were significantly less similar.

The number of activities chosen by the children was reliably similar for MZ but not for DZ pairs. Specific activities, however, were chosen entirely according to peer group standards, and both MZ and DZ co-twins preferred similar activities to a slight extent. Although no differences were found between MZ and DZ pairs in the choice of active or sedentary games, two authors found greater MZ similarities in the choice of sports among adolescent male twins. Gedda (1960) and Grebe (1956) studied competitive athletics, where successful participation is related to some characteristics with high heritability like physical size, body build, and agility. Girls' games are seldom tests of athletic ability and are more likely to be chosen because they are popular with peers.

Anxiety showed strong genetic influence. The evidence of heritability among grade-school girls supported several earlier studies, all of which reported high heritabilities for anxiety in normal and psychiatric populations (Carter, 1933, 1935; Eysenck, 1956; Eysenck & Prell, 1951; Gottesman, 1963; Shields, 1954; Slater, 1953). Individual differences in levels of anxiety are consistently found to be genetically determined in large part, regardless of the test used, the age, sex, or mental health of the populations. Anxiety has been studied extensively with adults but not as frequently with children; it is interesting to find similar genetic evidence for anxiety in a young group.

Patience versus impatience or impulsivity was also found to have genetic contributions in this as well as other populations. Vandenberg (1962), using the Thurstone Temperament Schedule, found significant heritabilities for four of the scales: Active, Vigorous, Impulsive, and Sociable. Gottesman (1963) found greater MZ similarities for seven of the ten clinical Minnesota Multiphasic Personality Inventory scales, several of which include impulsivity.

The results of this study suggest that several empirically defined aspects of activity motivation have moderate heritability. Better measures of different populations will further define the genetic contribution to activity motivation.

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