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The Determinants of Leadership: The Role of Genetic, Personality, and Cognitive Factors

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Abstract

A sample of 646 male twins (331 monozygotic or identical, 315 dizygotic or fraternal twins) completed a survey indicating their leadership role occupancy in work settings. Data on these individuals were also available for personality and cognitive variables. As predicted, two personality variables (Social Potency and Achievement) and a cognitive variable (a vocabulary test) were significantly correlated with the leadership variable. Subsequently, univariate and multivariate genetic analyses showed that a substantial portion of this leadership variance was accounted for by genetic factors (39 percent) while non-shared (or non-common) environmental factors accounted for the remaining variance in this leadership variable. Genetic influences were shown for the personality and cognitive factors as well. Finally, results indicated that the genetic influences for the leadership factor were substantially associated with or common with the genetic factors influencing the personality factors but not with the cognitive variable.

The Determinants of Leadership: The Role of Genetics, Personality, and Cognitive Variables

What are the determinants of leadership in work and organizational settings? This question has been pursued for decades. Throughout the years, a variety of constructs and predictors have been posited as determinants of leadership including general intelligence, personality, values, and even genetic factors. Though the proposition that individual differences or “traits” can predict and/or explain differences in emergent or effective leadership has sometimes been viewed with skepticism, current research has more firmly established the robustness of these types of variables in predicting leadership criteria. For example, Judge, Bono, Illies, and Gehrardt (2002) present the results of their meta-analysis showing that personality variables are consistently and reliably correlated with leadership variables, Chan and Drasgow (2001) demonstrate that a number of cognitive, personality, and motivational constructs are related to leadership across samples from different international environments, and Schneider, Paul, White, and Holcome (1999) show that a variety of constructs drawn from personality, interests, and motivation domains predicts leadership among high school students.

Because of the firm foundation regarding the relationships between the constructs of individual differences and leadership, it is not far-fetched to ask whether leadership is genetically influenced. Indeed, the notion that leadership has genetic influences has been articulated in practitioner and scholarly articles over the years. For example, in a recent Harvard Business Review article, Sorcher and Brant (2002) say: “Our experience has led us to believe that much of leadership talent is hardwired in people before they reach their early or mid-twenties" (p. 81). In contrast, Kellaway (2002) reports the efforts of a major US Bank to develop all of its employees (95,000 of them) into leaders, reflecting the belief that leadership is entirely under developmental influences. It is interesting to note that almost no research exists that examines this "nature-nurture" issue using a contemporary behavior genetics research design, even though Bass (1990, p. 911) and Arvey and Bouchard (1994, p. 70) suggest that such analyses would be quite appropriate. In addition, Arvey and Bouchard (1994) indicate that while there may be evidence for genetic influences on variables like leadership, such relationships are most likely mediated through other intermediate constructs (i.e. psychological and physiological variables). The current study explores the relationships of different personality and cognitive constructs with leadership as well as the roles genetic influences play in these associations.

Background: Several literature bases are important in developing the model and objectives for this study.

First, the research base establishing a genetic basis for leadership is limited. To our knowledge, only one previous study has examined this issue. Johnson, Vernon, McCarthy, Molson, Harris and Jang (1998) report the results of a study using 183 MZ and 64 DZ same-sex twin pairs. The Multifactor Leadership Questionnaire (MLQ ; Bass & Avolio, 1991) and other leadership measures (e.g. adjective checklist items) were completed by these twins. Two factors resembling transactional and transformational leadership dimensions were derived from MLQ items by factor analytic procedures. Results indicated that 48% and 59% of the variance in the transactional and transformational leadership dimensions respectively was associated with genetic factors.

The data also indicated that the genetic factor for the transformational dimension reflected a non-additive or dominant effect—that is, the impact of one gene depends on influence of another instead of simply "adding up". Other analyses showed that there were common genetic factors in the covariance found between these two leadership dimensions from the MLQ and several other leadership scales. This is an important entry into the research issue of whether leadership has some genetic associations. We expand on this research in several ways. First, we incorporate alternative measures of leadership that focus on leadership role occupancy that are perhaps more clearly distinguishable from other measured facets of leadership style. Second, we incorporate an expanded model proposing and testing a model of the determinants of leadership proposing that cognitive and personality variables are related to role occupancy (see below). This is important because simply showing that a construct is heritable leaves many unanswered questions regarding how the genetic mechanisms work and through which processes. Moreover, we investigate whether and to what degree any observed relationships between personality and cognitive variables and our leadership variable are due to common genetic factors.

A second literature base has to do with the research demonstrating relationships between personality dimensions and leadership. While a number of studies have demonstrated that personality variables are useful in predicting various aspects of job performance (Barrick & Mount, 1991, Hough, 1992; Lord, DeVader, & Alliger, 1986), there is also evidence that such variables predict a variety of leadership criteria. As mentioned above, Judge, Bono, Ilies, and Gerhardt (2002) meta-analyzed 222 correlations from 73 samples providing personality data according to the five-factor model (Digman, 1990) and found that measures of Extraversion correlated .31, measures of Conscientiousness correlated .28, measures of Openness correlated .24, and measures of Neuroticism correlated -.24 with leadership emergence (after corrections for unreliability but not range restriction). Similar findings have been reported previously by Hogan, Curphy, and Hogan (1994), Yukl (1998), Bass (1990), and Daft (1999). Thus, there is a substantial research base establishing a link between personality variables and leadership.

In addition, the genetic basis for personality is well established dating back to Loehlin and Nichols (1976). Since then similar results have been obtained for a variety of personality measures. A few examples include the study by Jang, Livesley, and Vernon (1996) who used a twin methodology where 123 pairs of monzygotic (MZ) twins and 121 dizygotic (DZ) twins were assessed using the revised NEO Personality Inventory (Costa & McCrae, 1992). This inventory is used to capture the five factors of personality mentioned above. The estimates of genetic influence (or heritabilities) of these dimensions were as follows: Neuroticism (41%), Extraversion (53%), Openness (61%), Agreeableness (41%), and Conscientiousness (44%). Using twin pairs (about 800) drawn from the National Merit Twin Study, Loehlin, McCrae, Costa, and John (1998) showed that the "Big Five" personality factors were substantially and comparably heritable with about 50% of the variance in these personality constructs being associated with genetic factors; however little or no influence due to shared family environment was found among these twin pairs. Similar estimates were obtained by Rieman, Angleitner, and Strelau (1997) using twin samples recruited for their study in Germany. Rowe (1994) summarizes his own earlier study (Loehlin and Rowe, 1992) where multiple studies and samples were analyzed which differed in terms of their genetic relationships (e.g. twins, parent-child, adoptive siblings, etc.) as well as other sample characteristics (e.g. different age groups, different geographical areas, etc.). The heritability estimates for the big five personality dimensions ranged from .39 to .49, with the heritability for Extraversion demonstrating the highest estimate (.49). Rowe concluded that "Individuals who share genes are alike in personality regardless of how they are reared, whereas rearing environment induces little or no personality resemblance" (Rowe, 1994, p. 64). Moving beyond personality measures relying on the Five Factor taxonomy, Tellegen, Lykken, Bouchard, Wilcox, Segal, and Rich (1988) report a study using twins who were assessed on the 11 major personality traits as measured by the Multidimensional Personality Questionnaire (MPQ, Tellegen, 1982). Their data indicated that genetic influences were significant and substantial for all 11 scales (ranging from .39 for achievement to .58 for constraint). For excellent contemporary reviews affirming the heritabilities of personality traits see Bouchard (1997) and Bouchard and Loehlin (2001).

Finally, there is a research base showing that measures of intelligence are correlated with leadership variables. For example, meta-analytic results reported by Lord, DeVader, and Alliger (1986) indicate that the mean true correlation of measures of intelligence and leadership is .50. Other reviews by Stogdill (1974), Bray and Howard (1983) and others support the intelligence—leadership relationship. More recently, Schneider, Ehrhart, and Ehrhart (in press) showed that one of the most consistent predictors of leadership in high school students was grade point average, a typical proxy of mental ability. There is also a robust research base demonstrating that general cognitive ability is heritable (Bouchard & McGue, 1981) where approximately 50 percent of the total variance of such constructs can be accounted for by genetic factors and about one quarter by shared environmental factors[1] (Plomin, McClearn, & McGuffin, 2001; Plomin and Rende, 1991). Thus, the inference that cognitive ability will be related to leadership and that a genetic component might underlie this relationship is not difficult to make.

Research Objectives. Given this background, the objectives of the present research are to investigate the following: 1) to affirm the relationships of a variety of personality, and cognitive ability measures with leadership, 2) to investigate the role of genetic influences in explaining these personality and mental ability constructs as well as leadership itself, and 3) to investigate the degree to which any observed relationships between these predictor constructs and leadership variables are due to common genetic influences.

Method and Results

Sample. The sample for this study was drawn from the Minnesota Twin Registry. The Registry is the product of an ongoing effort to locate as many as possible of the 10,000 surviving intact twin pairs born in Minnesota from 1936 to 1981 (Lykken, Bouchard, McGue, & Tellegen, 1990). The Minnesota Twin Registry subsample examined in the present study was assessed as part of the Minnesota Parenting Project, a broad study of life outcomes in men born between the years 1961 and 1964. The sample was restricted to men born in those years in order to hold age, sex, and birth cohort relatively constant. For purposes of this study, the relevant aspect of the sample was that it was representative of young working-age men born in Minnesota during this time. We sent surveys to 558 male twin pairs (1,116 individuals) who participated in this earlier study. A total of 646 completed surveys were returned, yielding a response rate of 58%. Of the 646 returned and completed surveys, 426 included both members of the twin pair. Of these 213 twin pairs (426 participants), 119 pairs were monozygotic twins and 94 pairs were dizygotic twins. As was their Minnesota birth cohort, the sample was primarily White (98%), and had an average age of 36.7 years (SD = 1.12). A total of 78% were married or living with a partner, 8% were divorced, separated, or widowed, and 14% were single. Other relevant characteristics of the total sample and twin types are presented in Table 1. The largest proportion of the sample described themselves as working in the production, construction, operating, maintenance, material handling (34.3%) or professional, paraprofessional, or technical (26.6%) occupations. No differences were observed between twin types on these variables.

The participants' zygosity had been determined as part of the Minnesota Parenting Project, using a five-item questionnaire that has been shown to exceed 95% accuracy compared to serological methods for establishing zygosity (Lykken, Bouchard, McGue, and Tellegen, 1990).

<u>Measures Used.</u> A variety of measures reflecting the different constructs were used. They are as follows:

<u>Leadership</u>: The definition and measurement of leadership has vexed researchers for years. Yukl (1998) and others have provided an overview of the major research approaches taken. These include the: 1) power-influence approach, 2) trait approach, 3) behavioral approach, and 4) situational approach. These different approaches are well known and articulated in many sources; thus, we will not repeat here a description of these various paradigms. For the present research, we measured leadership from a leadership “emergence” perspective where leadership is defined and measured in terms of

the various formal and informal leadership role attainments of individuals in work settings (see Judge, et al., [2000] for a discussion of “emergence” versus “effectiveness” leadership distinctions). We focused exclusively on leadership in work because of its relatively greater interest to behavioral scientists in this area (e.g. industrial psychologists).

Our leadership measure was developed using a “bio-history” methodology where respondents indicated past participation or role occupation in leadership positions. The bio-history or biographical approach to psychological measurement is a well-known and acceptable procedure in assessing autobiographical or historical events among individuals (Mumford & Stokes, 1992), including assessments of leadership potential and effectiveness (Stricker & Rock, 1998; McElreath & Bass, 1999; Chan & Drasgow, 2001). Respondents in our study replied to several items: 1) List the work-related professional associations in which they served as a leader (m=2.23, s.d.=.58), 2) Indicate whether they had “taken charge of a special project”, 3) Indicate whether they had “planned or coordinated a special event” at work, and 4) Indicate whether they had held positions at work that would be considered managerial or supervisory in nature (a number of different options were presented, e.g., manager, supervisor, director, vice-president, etc.). Table 2 presents the sample responses to these items. Chi-square analyses revealed that the monozygotic twins had held significantly more work group and director leadership positions on the job ($p < .05$) than the dizygotic twins. No other differences were observed.

We developed four initial scores for each individual for leadership role occupancy. The first score was developed by assigning 7 points if he checked President (the highest ranking category), 6 points if he checked Vice-President (the next highest-ranking category) but not President, 5 points if he checked Manager but neither of the other 2 higher ranking categories, etc. We standardized this score. A second score was developed based on the number of leadership roles assumed in professional associations (standardized). A third score was based on whether the individual had taken charge of a special project (standardized), and a fourth score was based on whether the individual had planned a special event (also standardized). We averaged across these four variables to create our leadership composite; we had no a-priori justification for providing differential weights for the four scores. We argue that this composite represents one form of a multidimensional construct—the aggregate model--discussed by Law, Wong, and Mobley (1998)[2]. This model is described as when a composite variable is formed by algebraically summing a number of other variables conceptually related to the construct of interest; the variables are not necessarily statistically interrelated nor does the resulting composite necessarily represent an underlying latent construct. There were 3 outlying observations on this scale, which were trimmed to a value 2.00. The mean for this composite scale was .00 (s.d.=.67, n= 646) with a range between –.87 to 2.00. There was a significant mean difference ($F=5.36$, $p<.05$) between monozygotic twins (m = .059) and dizygotic twins (m = -.065), but the effect size was relatively small between these two groups (.18). The scale correlated significantly ($p<.01$) with scales formed using similar items where respondents reported their past leadership activities in high school (.21), college (.18), and in current community activities (.22).

Other psychometric properties of this scale behaved as expected. For example, the scale was not significantly related to a number of variables for which there were no a-priori expectations of a relationship (i.e., marital status, etc.), it was negatively correlated with variables for which a reverse relationship was expected (i.e. those who lived on a farm scored lower on this scale, -.10), and it was positively correlated with total household income ($r=.23$, $p<.01$)—a reasonable expectation (Kuhn & Weinberger, 2002). Finally, in an effort to verify that individuals were indeed in the leadership roles that they indicated, we conducted telephone interviews with 11 individuals who were among the top scorers on this variable. We asked them to provide additional details concerning the various roles they occupied (e.g. how many people they supervised, what kinds of responsibilities were involved, etc.) In almost every case, there was sufficient data for us to feel that the information provided was verified.

<u>Personality measures</u>. The 198-item form of the Mutidimensional Personality Questionniare (MPQ; Tellegen, 1982; Tellegen & Waller, 2001) was administered to the larger twin population from which this sample was drawn. This inventory yields scores on 11 primary trait scales developed through factor analysis. The mean 30-day test-retest reliability is .87 for these MPQ primary scales. It is important to note that the sample (and larger population) completed this inventory as part of a separate survey six years earlier than the survey administered regarding the leadership measures described above. Thus, there was a considerable time difference between the completion of this personality inventory and the leadership survey. This reduces the possibility of inflated correlations due to same-time method bias and establishes some plausibility for the premise that personality predicts leadership rather than vice-versa. As mentioned in the introduction, the trait scales based on the MPQ scales have demonstrated relatively high heritabilities based on other samples. Also, while the trait scales from the MPQ do not map exactly

onto the taxonomy provided by the Five Factor organization of personality dimensions, there is sufficient similarities between several of the dimensions and facets subsumed under the Five Factor structure (see Hough & Ones [2002} and Bouchard & Lochlin [2001] for a cross-walk between the Five Factor model and the MPQ scales and Church [1994] for an empirical examination of the relationships between MPQ scales and Costa & McCrae's [1995] NEO Personality Inventory, which directly measures dimensions organized around the Five Factor model). We selected the three scales from the MPQ that are most relevant to leadership—Social Potency, Achievement, and Social Closeness. A description of these three scales is provided in Appendix A. The choice of these three scales was based on several factors. First, the Social Potency scale corresponds well with the Extroversion dimension of the Big Five and, as mentioned in the introduction, the Extroversion dimension showed the highest meta-analytically derived correlation with leadership (.31). Second, Judge, et al. (2002) showed that the lower-order dominance trait of the Extroversion dimension showed a relatively high (.37) correlation against leadership criteria (see Table 3 in Judge, et al., 2002). Similarly, the MPQ Achievement scale corresponds to the lower order personality trait of achievement also shown by Judge, et al. (2002) to be highly correlated (.35) against leadership criteria. In addition, the MPQ Achievement scale is indicated as being rationally and empirically similar to the Conscientiousness factor in the Five Factor model (see Hough & Ones [2002] and Table 3 in Church [1994]). This Conscientiousness dimension also shows a relatively high meta-analytic correlation against leadership (.29) according to the Judge et al (2002) study. Finally, the Social Closeness MPQ scale empirically maps onto the Extroversion dimension of the Five Factor model (see Table 3, Church, 1994) and is conceptually similar to the lower order personality trait of sociability shown by Judge et al. (2002) to be correlated against leadership criteria (.24). The correlations between these three MPQ scales ranged from -.07 to .35 and were thus relatively independent of each other. Based on these previous findings, we predict these three MPQ scales to be significantly correlated against our measure of leadership emergence.

Cognitive Measure: The verbal component of the Weschler Adult Intelligence Scale (WAIS-R) was administered over the telephone to a random subset of the individuals as part of their earlier participation in the Minnesota Parenting Project. Like the MPQ, this test was administered several years prior to the present investigation. It should be noted that only a subsection of the sample had these data available (n=346). The mean for the Vocabulary score was 46.4 (s.d.=11.8); MZ's scored significantly higher (m = 48.0) than DZ's (m = 43.9) on this measure (F= 10.40, p< .01).. The means, standard deviations for the personality, cognitive, and leadership variables are shown in Table 3.

Analytical Approach. As a first step in the analyses we correlated the various personality and cognitive variables against the leadership variable. These values are also shown in Table 3. It is clear from these single-order correlations that the leadership variable is significantly correlated against all four of these variables as predicted. The MPQ scale of Social Potency showed the highest correlation (.35) whereas the Social Closeness scale showed the lowest (.15). The multiple correlation coefficient (.40) between these variables and leadership was also significant at the .01 level but the Social Closeness variable did not exhibit a significant beta-weight (p <.40) and therefore this variable was dropped from further analyses.

The second step in our analyses was to estimate the amount of variance in the various measures due to genetic and environmental components. Our quantitative genetic model is based on the assumption that the observed phenotypic variance (Vp) is a linear additive function of genetic (Vg) and shared (Vs) and non-shared (Vn) environmental variance, respectively. Symbolically,

$$Vp = Vg + Vs + Vn.$$

Under this model, the non-shared environmental variance represents residual variance not explained by either of the other two sources, confounded with measurement error.

The expected covariance between any two members of a twin pair as a function of the variance components given above can be specified as,

$$COV_{(MZ)} = Vg + Vs$$

$$COV_{(DZ)} = .5*Vg + Vs$$

Vg, or the proportion of the total variance attributable to additive genetic sources, can therefore expressed as:

$$Vg = 2[Cov(_{MZ})\text{-}Cov(_{DZ})].$$

Or alternatively as:

2(MZ intraclass correlation-DZ intraclass correlation)

where intraclass correlations are calculated separately for the monozygotic (MZ) and dizygotic (DZ) twins using the formula:

$$(MSB\text{-}MSW)/(MSB + MSW), \qquad (1)$$

and MSB is the Mean Square Between twin pairs and MSW is the Mean Square Within twin pairs from a One-way Analysis of Variance with twin pairs as the independent variable.

Heritability estimates are based on several assumptions. The first is that twins (both MZ and DZ) are representative of the population as a whole for the trait in question. For personality traits, in particular as measured by the MPQ, this appears to be the case (Johnson, Krueger, Bouchard, & McGue, 2002). Second, we assume that MZ twins share environmental influences to the same degree as DZ twins. Several attempts have been made to uncover circumstances in which this assumption does not hold, with generally negative results. We attempted to test the validity of this assumption in this sample. A portion of the sample had completed a questionnaire assessing the degree of closeness of their relationship with their co-twin. For the MZ pairs that provided these data, the closeness of the twin relationship was not related to the twin similarity on the leadership variables[3].

Another assumption is that there is no assortative mating (meaning that the parents of the twins were not similar) for the traits in question. When present, assortative mating tends to increase DZ twin correlations, but has no effect on Mz twin correlations. Thus, because some assortative mating (with coefficients ranging from .10 to .20) exists for most personality-related traits (Price & Vandenberg, 1980), this assumption generally has the effect of understating heritability estimates. Such relatively small values, however, are unlikely to reduce estimates of genetic influence substantially. We also assume that there are no genetic and environmental interactions. Again, though the concept of such interactions has great intuitive appeal, few replicable genotypeenvironment interactions have been found (Plomin, DeFries, & McClearn, 1988), although progress is being made in terms of detecting such interactions (Rutter & Silberg, 2002; Legrand, McGue, & Iacono, 1999).

The final assumption is that the genetic variance is additive in the sense that if multiple genes influence the trait, they do so independently of each other. Violations of this assumption could mask shared environmental effects in reared-together twin studies, but without reared-apart twins, we have no way of addressing the extent to which the assumption holds in the current study.

For the purposes of conducting our various genetic analyses we wished to remove skew from the leadership variable and therefore performed a log-transformation of this variable, re-standardized it, and multiplied it by 100. To place the personality and cognitive measures on the same scale as the leadership variable, they were likewise standardized and multiplied by 100.

Table 4 shows the twin intraclass correlations for the personality and leadership measures, along with heritabilities they imply. As reported in other studies, the MPQ scales we used showed strong heritabilities. Of note is that the leadership variable demonstrated an implied heritability of .55, a considerably high value.

At this point of our analyses, there was fairly good evidence for the heritabilities of the various independent predictor variables in our model as well as for the leadership variable. However, more sophisticated analyses can be applied 1) to provide more accurate estimates of heritabilities, 2) to separate environmental influences into shared and non-shared environmental sources and 3) to provide more clear estimates of the extent to which there are common influences among the predictor and the leadership variables. To this end, we first estimated the genetic influences (along with estimates of the influences of shared and non-shared environmental factors) associated with each of the variables derived from our leadership model using standard structural equation modeling procedures and the method of maximum likelihood as operationalized in the software program Mx (Neale, 1994). Using the separate trait covariance structures for the MZ and DZ twins, the procedure models the influencing factors according to the assumptions outlined above. The basic model for twin data includes three factors that influence an observed measurement (phenotype) or latent variable: additive genetic effects (A), common environmental effects, i.e. influences shared by members of the same family (C), and non-shared environmental effects and/or error (E). As shown in equation 2, variance in a phenotype can be expressed as the sum of variance attributable to each of the three factors, A, C, and E., each weighted by a parameter (h, c, or e) that determines their relative influence:

$$V_{leadership} = a^2 + c^2 + e^2 \qquad (2)$$

Figure 1 presents the path model used to describe the relationships among the variables for two individuals who are either MZ or DZ twins. This is the path model used for the present analyses and is found in Heath et al. (1989). The paths e, a, and c represent the relative influences of the non-shared environmental, additive genetic, and shared environmental latent variables on an observed or latent leadership variable. MZ twins share all their genetic material, thus the correlation of 1.0 between the additive genetic components of Twin 1 and Twin 2 of the MZ pair; DZ twins share, on average, one half of their genes so that the corresponding correlation is .5 for the DZ twins. The common environment between pair members of both twin sets is set at 1.0, reflecting the assumption of equal common environmental influence, whereas the path between the non-shared environmental factors for the twins is, by definition, specified as zero. The modeling procedure estimates the three proportions, and reports the degree to which the resulting parameter estimates fit the assumptions.

Table 5 shows these results of these structural equation heritability analyses for the different variables in our model. Perhaps of greatest importance is to examine the heritability of the observed leadership variable[4]. The heritiability was .47 (95% confidence interval .09-.58) for this variable. To evaluate model fit we reviewed both the Akaike Information Criterion (AIC; Akaike, 1983) and the RMSEA. The AIC=Chi-square statistic-2df provides a summary index of both model fit and parsimony; models that have large negative values of AIC are preferred over those with smaller negative or positive AIC values. As can be seen, the univariate model fit particularly well for the leadership variable—the RMSEA was .00 and the AIC value was negative[5]. Thus, there is good evidence for genetic influence for this observed variable. Also, the variance accounted for by the shared environmental factors was estimated as zero, whereas the non-shared environmental and/or measurement error factor accounted for the remaining amount of the variance (.53) for this leadership variable.

Also, as shown in Table 5, there is good evidence for the heritabilities of the two personality variables as well (above .40) and the values observed are quite close to those obtained by Tellegen et al. (1988) for these specific variables. Also, of note is that the shared environment played almost no role in accounting for the variance for these variables as well. The genetic influence for the Vocabulary variable was .43, a value somewhat lower than what might be expected given the extensive research on the heritability of this variable. This lower value might be due to a more restricted range on this variable compared to a full-scale IQ measure. The proportion of variance due to the shared environment component was .28 for Vocabulary, which is also slightly deviant from previous research findings showing lower or no contribution of this component. The fit statistics for this particular variable were not strong either.

The results from the structural equation models presented thus far only provide estimates of the variance in each particular measure associated with genetic and environmental factors. We are also interested in the extent to which the relationship between each of the predictors and leadership is genetically or environmentally mediated. To determine the later, multivariate models are needed. These multivariate models are direct generalizations of the univariate models, and allow estimates of the extent to which two measures share genetic influences (the genetic correlation), shared environmental influences (the shared environmental correlation), and non-shared environmental influences (the non-shared environmental correlation).

To fit this model, we made use of the expectation-maximization algorithm to estimate MZ and DZ variance-covariance matrices. This procedure relies on maximum likelihood estimation procedures to generate the variance-covariance matrices making use of all available data, whether or not the data are complete for each individual. This method relies on the assumption that whatever data are missing are missing at random in the sense of the Little and Rubin (1987) discussion. We believe that this assumption was defensible because the process that generated the missing data (i.e., different questionnaires administered to different portions of the sample at different times) had nothing to do with the variables being observed and because there were no significant differences on other variables used in our study between those individuals for whom cognitive data were collected and those who did not have such data.

The results of our analyses revealed that because the maximum likelihood surface was relatively flat, there were two solutions with similar fit statistics. (Chi-square values of 23.2 and 22.9 with 52 df, p=.99.). We present the solution (Chi-square = 23.2) that provided heritability estimates that most closely resembled those obtained from the above univariate analyses. However, the proportion of variance estimates and the genetic correlations from both solutions were similar[6]. Table 6 shows the proportions of variance attributable to genetic, shared environmental, and non-shared environmental sources for each of the traits based on this model. The fit statistics for this model were: AIC = -80.80 and the RMSEA = .000 indicating a very good fit.

Again, the proportion of variance attributed to genetic influences for the leadership variable was relatively high (.39). As with the univariate model, no variance is attributed to the shared environment component. In some contrast with the univariate analysis, the proportion of variance attributed to genetic influences on vocabulary was only .39, but no variance was attributed to the shared environment. This finding is more consistent with previous research findings. Similar values were observed for the two personality variables, though the estimate of genetic influence is still relatively low.

The structural equation analyses also generated several interesting correlational results. First, the modeled phenotypic (or observed) correlations of the personality and cognitive factors with the leadership variable was .36 for Social Potency, .23 for Achievement, and .06 for the vocabulary variable, indicating that the personality factors were relatively more important than the cognitive factor in their association with the leadership variable.

Second, the genetic correlations between the various personality and cognitive variables and the latent leadership variable were generated. The genetic correlation reflects the extent to which whatever genetic variance is associated with two variables is likely to be in common. The squared value of a genetic correlation represents the proportion of the heritability of the latent leadership measure that can be explained by the genetic factors affecting each of the personality and cognitive factors. Consider two completely heritable traits such as eye and hair color. Though heritability is 100% for each, the genetic correlation is much lower, though it may not in fact be zero, as dark eyes and hair tend to be found in the same person, as do blue eyes and blonde hair.

These data indicate that a substantial amount of the genetic influence on the leadership variable was common to the personality variables. The genetic correlation between the Social Potency and Leadership variable pair was .61 indicating that 37 percent of the genetic variance for leadership is shared or in common with that of the Social Potency. The genetic correlation between the Achievement and Leadership variable pair was .42, indicating that .17 percent of the genetic variance for leadership is shared with this personality factor. On the other hand, the genetic correlation for the Cognitive and Leadership pair was only .07, indicating that less than 1 percent of the genetic variance accounting for Leadership is in common with the Cognitive factor.

One further question concerns the percentage of the genetic variance in leadership that is due to both personality and cognitive ability jointly. To estimate this, one can add the proportions of variance to the extent to which they are independent. Achievement and Vocabulary and Vocabulary and Social Potency are virtually independent (correlations are .01 and .07 respectively) and Social Potency and Vocabulary are correlated .18, so their common variance is 3%. Accordingly, the percentage of the genetic variance due to both personality and vocabulary would be 37% from Social Poise, plus 17% from Achievement, plus 1% from Vocabulary minus the common variances for a total of 53%. This is an approximate value, however.

One of the objectives of the present research was to investigate the degree to which personality and cognitive variables would mediate any genetic influence observed. These data suggest that the relationship between the personality and leadership variables is mediated through a common genetic mechanism to some degree, but that genetic influences on cognitive ability and leadership are independent. The genetic influences on leadership are mainly dispersed amongst the two different personality factors but a substantial amount of genetic influence on leadership operates through other mechanisms and variables.

Finally, because the proportion of variance accounted for by shared environmental factors for variables were estimated to be zero, there can be no shared environmental correlation, or it would be based on trace variances; we therefore do not report or comment on these values. The non-shared environmental correlations were like-wise quite low (equal to or below .05).

Discussion

This study was largely exploratory in nature. We were interested in examining the roles of different constructs of individual differences in predicting leadership. We were also interested in the role of genetic influences in explaining these constructs as well as any observed covariation among them. This research demonstrated that personality and cognitive factors predicted leadership in this sample, that these relationships were substantial, and that they accounted for a sizable portion of the variance—a not surprising set of findings given the extant literature.

However, very little research has explored the combination of personality and cognitive factors in predicting leadership and even less has explored the underlying genetic and environmental influences involved. Thus, this research offered new evidence in this arena. Findings clearly indicated that genetic factors influence the personality, cognitive, and leadership factors derived in this study and confirmed earlier research showing that personality and cognitive factors have strong genetic influences.

Of perhaps most interest in this study is the finding that the leadership variable had an estimated heritability of .39 (based on the multivariate model), meaning that 39 percent of the variance in this factor was accounted for by genetic factors. Non-shared environmental influences accounted for 61 percent of the variance. Shared or common environmental factors such as family-wide influences were essentially non-influential for this variable, accounting for zero percent of the variance. The findings in this study also revealed that some of the genetic factors that influence leadership are the same or similar to the genetic factors influencing personality variables but there is little common genetic influence for the cognitive and leadership variables. It is also very important to keep in mind that almost half the genetic variance in leadership is not shared with the various personality and cognitive measures, suggesting that leadership may have other independent genetic influences as well.

It is very important to under-score the findings here that while genetics influences account for a sizable portion of leadership variance, environmental factors are substantially important in determining leadership. The question of whether leaders are “born or made” is perhaps a red herring. Leadership is a function of both the environmental and genetic factors that impact individuals—not one or the other. What is of great interest is the question of determining more precisely the kinds of environmental experiences that are most helpful in predicting and/or developing leadership and the ways in which these experiences possibly interact and/or correlate with genetic factors. Also, there is a need to explore the potential developmental processes associated with leadership and whether genetic and environmental influences might vary across the careers of individuals. Perhaps there is some age-dependent change such as that observed with cognitive variables where the proportion of genetic influence increases throughout development (McGue, Bouchard, Iacono, & Lykken, 1993).

It is also important to recognize that the estimates for genetic influence obtained here were sample-specific. Thus, other samples from other populations with perhaps different variable ranges will yield other estimates. For example, it would be of great interest to replicate this study using females subjects. In addition, because a variable or construct exhibits a genetic influence does not mean that it is unchangeable. Environmental interventions can have sizable impact on samples and populations, even when a trait is highly heritable (Maccoby, 2000).

Limitations. There are a number of potential issues and/or limitations with this study that need to be recognized. Perhaps the first is the issue of whether the measure of leadership we utilized was appropriate. For example, leadership might have been conceptualized as inspirational or charismatic behaviors rather than as role occupancy as used in the present study. This well may be true, but we believe that the role occupancy measure might represent possibly better and more objective "threshold" indices. It is more likely than not that individuals in positions of authority, supervision and management, etc. will be regarded as leaders, at least formally within their respective organizations. There also may be some restriction of range on the leadership measure we used. The sample of male twins studied were relatively young and in mid-and early career stages; thus limiting the number of leadership roles that might be available to them at the time they were surveyed. We also do not address the issue of leadership effectiveness. It may well be that the genetic factors that influence leadership effectiveness differ from those that influence leadership emergence.

A second issue concerns the self-report nature of our survey data. It could be that individuals falsely reported their leadership roles and behavior. This, of course, is the issue of whether the variables we examined were valid. We reported a variety of evidence indicating that the measures used were construct valid as exhibited through the demonstration of their relationships with other variables—that is, they were imbedded in a network of relationships with other variables that made sense (Arvey, 1992). In addition, previous research associated with the bio-history method has demonstrated good verifiability and accuracy of such measures. Certainly, future research should consider the use of alternative methods and metrics in measuring leadership when further exploring the role of genetics and leadership. For example, it would be interesting and informative to gather data from peers and associates of individuals regarding both leadership and personality evaluations of a targeted twin sample.

The issue of common method variance is also a concern, as in any situation where participants completed all instruments. However, many of these scales and scores were gathered at different points in time separated by as much as six years, which should offset this difficulty to some degree.

Even though a total of 646 subjects were used in the present study, this is not a large sample given the nature of the modeling methods used, which typically require fairly large N sizes to develop precise point estimates and confidence intervals. Thus, replication of this research across different samples of twins using different measures of leadership and its individual differences antecedents is critical. Different methodologies (including adoptive and other designs) would also be valuable.

Finally, we note that we have done nothing to identify specific genes or environmental characteristics associated with leadership and leave this task to future research efforts.

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Footnotes

[1] The amount of variance accounted for by shared environmental factors decreases over the lifetimes of individuals (Plomin, et al., 2000).

[2] This form is alternatively described in personnel research literature as a “heterogeneous” criteria or composite variable that does not necessarily need to demonstrate inter-relatedness among its subparts (see for example, Schmidt & Kaplan (1971).

[3] We used only the MZ twins for this analysis because we can be sure of the degree of genetic relationship between them. DZ twins share, on average, 50% of their genes and thus there is uncertainty regarding the genetic similarity between any two same pair DZ twins.

[4] For this particular set of analyses we “double entered” the data meaning that the data for each twin was entered twice—once as the first twin and once as the second twin. This is helpful when there are potential variance differences among twin types.

[5] For this variable, we also examined the fit for a model that included environmental factors only. The observed fit statistics were worse (and statistically worse) under this model compared to the full model described above.

[6] E.g., the proportion of variance estimate for the leadership variable was .31 for the alternative solution, compared to .39 for the solution we present.

Appendix A

Content Summary of the MPQ Scales Used in Study

Scale Name	Description of High Scorers	Description of Low Scorers
Social Closeness	Is sociable, likes people; takes pleasure in, and values, close interpersonal ties; is warm and affectionate; turns to others for comfort and help	Likes being alone; does not mind pulling up roots; is aloof and distant; prefers to work problems out on own
Social Potency	Is forceful and decisive; is persuasive and likes to influence others, enjoys or would enjoy leadership roles; takes charge of and likes to be noticed at social events	Prefers others to take charge and make decisions; does not like to persuade others; does not aspire to leadership; does not enjoy being the center of attention
Achievement	Works hard; likes long hours; enjoys demanding projects; persists where others give up; puts work and accomplishment before many other things; is a perfectionist	Does not like to work harder than is strictly necessary; avoids very demanding projects; sees no point in persisting when success is unlikely; is not terribly ambitious or a perfectionist

Table 1

Sample Characteristics

	Monozygotic N = 334	Dizygotic N = 316	Total N = 650
Age	M=36.71 s.d .=1.13	M=36.76 s.d.=1.10	M=36.73 s.d. .=1.12
Occupation			
Managerial & Administrative	20.7%	16.5%	18.6%
Professional, Paraprofessional & Technical	28.4%	24.7%	26.6%
Sales & Related	11.1%	10.1%	10.6%
Clerical & Administrative Support	.6%	.6%	.6%
Service	6.9%	9.5%	8.2%
Agricultural, Forestry, Fisheries & Related occupations	3.3%	6.0%	4.6%
Production, Construction, Operations, Maintenance, and Material Handling	31.4%	37.3%	34.3%

Table 2

Sample Responses on Bio-History Leadership Items

	MZ N=334	DZ N=316	Total N=650
Taken charge of a special project	62.3%	60.1%	61.2%
Planned or coordinated a special event	47.3%	39.9%	43.7%
Number of Professional Associations Where Leadership Played a Role			
1	12.3%	10.4%	11.4%
2	6.3%	5.7%	6.0%
3	3.0%	1.9%	2.5%
4	0.9%	1.3%	1.1%
5	1.2%	0.6%	0.9%
6	0.0%	0.2%	0.2%
7	0.6%	0.6%	0.6%
Hold or Have Held a Position			
Work Group Leader	38.6%*	29.7%	34.4%
Team Leader	36.8%	25.07%	31.2%
Shift Supervisor	22.5%	19.2%	20.9%
Manager	37.3%	26.6%	29.5%
Director	10.8%*	5.17%	8.0%
Vice-President	4.2%	4.4%	4.3%
President	7.5%	6.3%	6.9%
Other	10.8%	15.8%	13.2%

*Chi-square analysis showed significant difference in percentage between monozygotic and dizygotic twins at p.<.05 level.

Table 3.

Means, standard deviations, and intercorrelations of leadership, personality, and cognitive ability measures.

	Mean	s.d.	1	2	3	4	5
1 Leadership	0.00	0.67	1.00				
2 Social Potency	49.28	9.89	.35**	1.00			
3 Social Closeness	49.03	9.91	.16**	.33**	1.00		
4 Achievement	49.22	9.91	.22**	.25**	-0.07	1.00	
5 Vocabulary (WAIS)	46.35	11.79	.17**	.27**	0.04	-0.05	1.00

*p <.05, ** p <.01

[a] Sample sizes vary; n = 345 for vocabulary, 533 for others

Table 4

Twin Intraclass Correlations for Personality and Leadership Measures

Measure	MZ	DZ	Implied Heritability
Social Potency (MPQ)	.58	.19	.79
Achievement (MPQ)	.47	.11	.72
Vocabulary (WAIS)	.77	.49	.56
Leadership	.48	.21	.55

Note: MZ = monozygotic twin pairs; DZ = dizygotic twin pairs.

Implied heritability determined by Falconer formula $2(r_{mz}-r_{dz})$.

Table 5

Maximum-Likelihood Model-Fitted Attributions of Variance for Personality and Leadership Measures

Measure	N pairs(MZ/DZ)	Genetics [a] A	Shared Environment [a] C	Non-Shared Environment [a] E	AIC	RMSEA
Social Potency (MPQ)	(106/69)	.55 (0-.54)	.00 (0-.38)	.45 (.34-.59)	-1.704	.071
Achievement (MPQ)	(106/69)	.43 (.04-.56)	.00 (0-.53)	.57 (.44-.72)	-2.701	.051
Vocabulary (WAIS)	(75/48)	.43 (.02-.78)	.28 (0-.65)	.29 (.21-.41)	.932	.149
Leadership	(119/94)	.47 (.09-.58)	.00 (0-.31)	.53 (.42-.67)	-4.883	.000

a = Values in parentheses represent 95% confidence intervals

Table 6

Multivariate Model-Fitted Attributions of Variance of Personality, Cognitive,

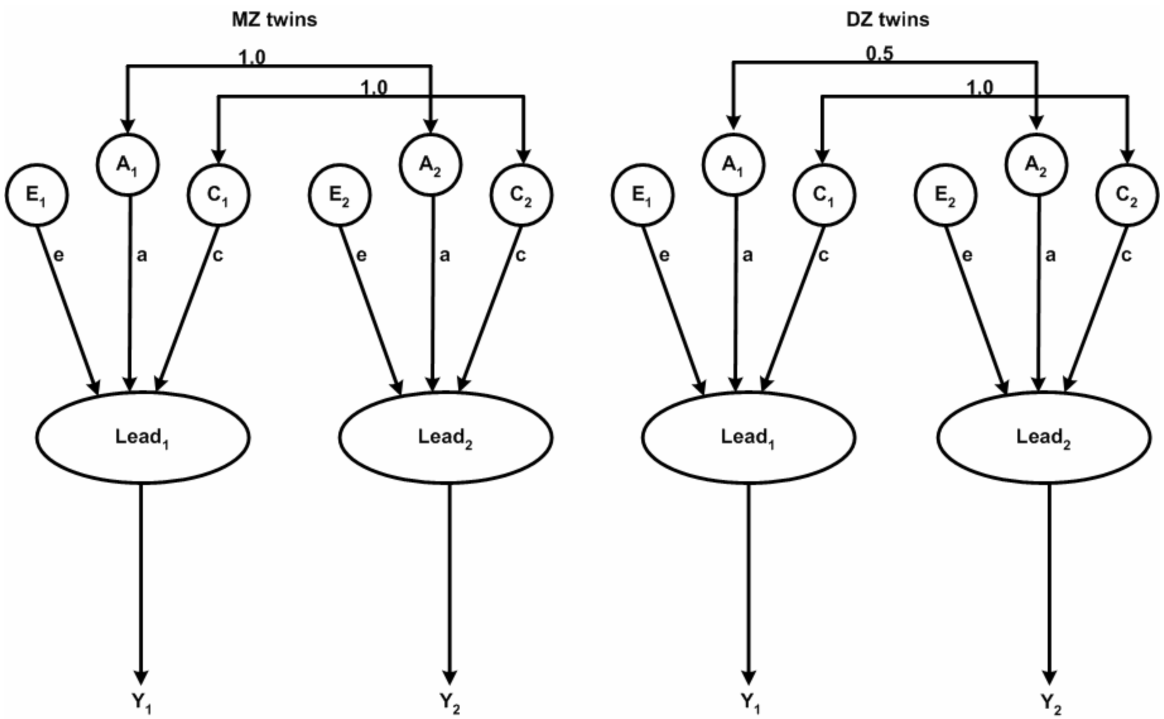
and Leadership Variables

	Proportion of variance due to		
Variable	Genetic	Shared Environment	Non-Shared Environment
Social Potency (MPQ)	.35	.00	.65
	(.06-.44)	(.00-.32)	(.49-.80)
Achievement (MPQ)	.30	.00	.70
	(.00-.40)	(.00-.34)	(.53-.94)
Vocabulary (WAIS)	.39	.00	.61
	(.05-.46)	(.00-.33)	(.48-.72)
Leadership	.39	.00	.61
	(.03-.48)	(.00-.38)	(.45-.76)

Note: 95% confidence intervals in parentheses.

Figure Caption

Figure 1. Univariate genetic model: E1, A1, C1, represent latent variables of nonshared environmental effects, additive genetic effects and shared or common environmental effects, respectively. Lead1 and Y1 represent the latent variable of leadership and its phenotypic measurement. Similar denotations are made for Twin 2.



MZ twins
1.0
1.0
A1
A2
E1
C1
E2
C2
e
a
c
e
a
c
Lead1
Lead2
Y1
Y2
DZ twins
0.5
1.0
A1
A2
E1
C1
E2
C2
e
a
c
e
a
c
Lead1
Lead2
Y1
Y2