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The determinants of leadership role occupancy: Genetic and personality factors

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Abstract

This study investigated the influence of genetic factor and personality on leadership role occupancy among a sample of male twins. Identical twins ($n = 238$) who share 100% of their genetic background were compared with fraternal twins ($n = 188$) who are expected to share only 50% of their genetic background. Results indicated that 30% of the variance in leadership role occupancy could be accounted for by genetic factor, while non-shared (or non-common) environmental factor accounted for the remaining variance in leadership role occupancy. Genetic influences also contributed to personality variables known to be associated with leadership (i.e., social potency and achievement). Furthermore, the results indicated that the genetic influence on leadership role occupancy was associated with the genetic factors influencing the personality variables, but there was no definitive evidence whether these personality variables partially mediated the relationship between genetic factor and leadership. Results are discussed in terms of the implications for leader selection and training.

Keywords: Leadership; Behavioral genetics; Personality

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 leadership emergence or leadership effectiveness has sometimes been viewed with skepticism, current research has more firmly established the robustness of these types of constructs in predicting leadership criteria.

For example, Judge, Bono, Ilies, and Gerhardt (2002) present the results of their meta-analysis showing that personality variables are consistently and reliably correlated with leadership emergence and leadership effectiveness. Chan and Drasgow (2001) demonstrate that a number of cognitive, personality, and motivational constructs are related to leadership potential across samples from different international environments. Further, Schneider, Paul, White, and Holcombe (1999) show that a variety of constructs drawn from the personality, interests, and motivation domains predict socio-emotional and task–goal leadership among high school students.

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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 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. Most researchers in behavioral genetics use some sort of twin design where monozygotic (identical) and dizygotic (fraternal) twins raised in the same family are studied with regard to their similarity on particular variables (e.g., IQ, personality, etc.). The assumption is that there is variation in terms of the twin types with regard to their genetic makeup (identical twins have 100% of their genes in common whereas fraternal twins have, on average, 50% of their genes in common), but because these twins were reared in the same family environment, an assumption is made that they have roughly the same environmental influences growing up. Other twin (identical twins reared apart) and adoption studies can help examine genetic issues as well.

In addition, Arvey and Bouchard (1994) and more recently Ilies, Arvey, and Bouchard (in press) 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 present study explores the relationships of different personality constructs with leadership as well as the role genetic influences play in these associations. The two broad goals of this study are 1) to estimate the heritability of leadership role occupancy in work setting, and 2) to estimate the extent to which genetic influences on this leadership criterion are realized though personality factors. Specific hypotheses are advanced below.

There are also important practical implications of research that investigates the degree to which leadership has genetic underpinnings because it simultaneously investigates how much environmental factors play a role in influencing leadership. Thus, the domain of leadership development can be informed by research that suggests how much leadership may be developed and perhaps, in the future, whether there are interactions among a variety of genetic and developmental components for fostering leadership at various points across the life span (Plomin, DeFries, McClearn, & McGuffin, 2001). One other application of the use of twin studies is that twins can serve as very good control subjects in investigating leadership development programs. One twin could be exposed to a leadership development program while the other is not.

1. Linkages among genetic, personality, and leadership variables

While the question of whether leadership has a genetic influence has been debated, there is no precise model or theory that we can easily adapt and use [with the exception of the Arvey and Bouchard (1994) model discussed below] for our predictions. Thus, like Schneider et al., (1999), we adopt a variation of the grounded theory approach articulated by Strauss (1988), where we review several literature bases to develop the model and objectives for the present study.

The first is a literature base showing that there is some limited evidence for a genetic basis of leadership. Second, there is more substantial literature showing that certain personality constructs are related to leadership. Finally, there is literature showing that these same personality components likewise have a genetic basis. These three linkages establish the theoretical structure that we will empirically explore. Based on these literatures, we form general and specific hypotheses.

1.1. Genetics—leadership linkages

The research that establishes a genetic basis for leadership is limited. To our knowledge, only two previous studies have empirically examined this issue. Johnson, Vernon, McCarthy, Molson, Harris and Jang (1998) report the results of a study using 183 identical and 64 fraternal same-sex male and female twin pairs. The Multifactor Leadership Questionnaire (MLQ; Bass & Avolio, 1991) and other leadership measures (i.e., 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 were 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 the influence of another gene instead of simply "adding up" the effects of the two genes.

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. Johnson, Vernon, Harris and Jang (2004) report a more recent study involving the same subjects. Subjects had completed the Personality Research Form (PRF) from which 20 trait scales were derived. Their analyses showed that the personality scales were heritable, were correlated with measures of transformational and transactional leadership, and that some of the genetic factors were associated with particular personality traits and leadership (i.e., there were significant genetic correlations). These two studies are important entries into the research issue of whether leadership has some genetic associations and whether the same genetic factors are common determinants of both personality and leadership.

We expand on this prior 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 self-reported facets of leadership style. Second, we test an expanded model of the determinants of leadership proposing that the relationships between genetic factor and leadership role occupancy are mediated by certain personality variables. 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. Fig. 1 presents an expanded model developed by Arvey and Bouchard (1994) where genetic differences among individuals are posited to impact a variety of work related variables, including leadership, as mediated by personality and other variables.

One recent study investigated these proposed linkages. Ilies, Gerhardt and Le, (in press) used path analytic methods to examine the linkages among genetic, personality, cognitive, and leadership emergence constructs. To this end, they used meta-analytically derived correlations among personality, intelligence constructs, and leadership emergence, along with other known estimates of the heritabilities of personality and intelligence to estimate the mediating impact of genetics on leadership.

The resulting estimate was that almost 20% of the variance in the latent construct of leadership emergence could be explained by genetic effects as mediated by intelligence and personality traits. However, no empirical evidence has been demonstrated to confirm this value. Thus, based on this extant literature, our hypothesis is that there will be a

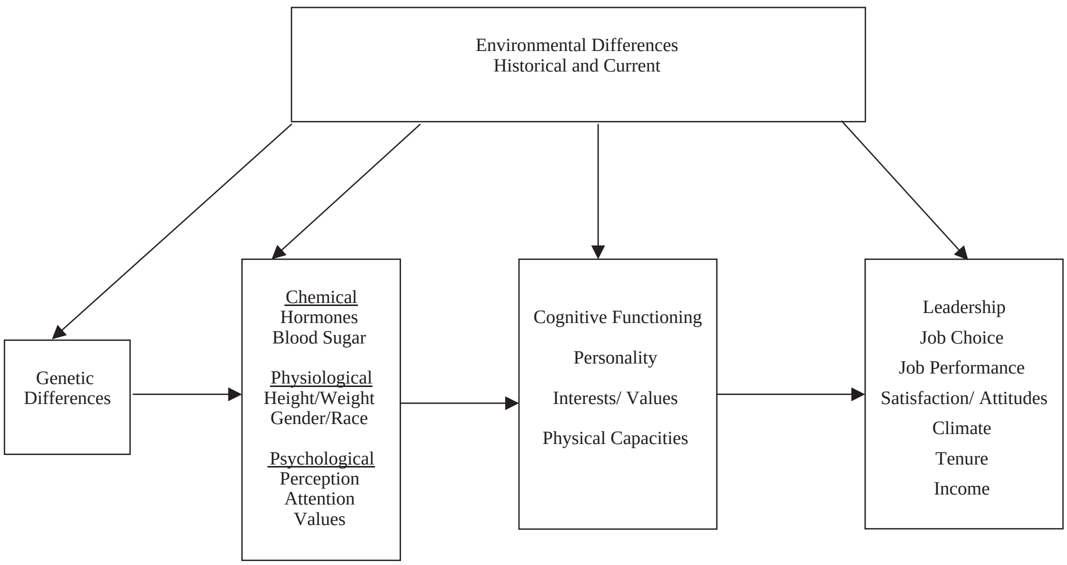

Fig. 1. Expanded model of genetic influences on work related variables, adapted from Arvey and Bouchard (1994).

significant and direct genetic influence on our leadership construct. An additional hypothesis is that observed genetic influence will be mediated through particular personality traits.

1.2. Personality—leadership linkages

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, DeVander, & Alliger, 1986), there is also evidence that such variables predict a variety of leadership criteria. As mentioned above, Judge et al. (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. The present study focuses on the three traits (i.e., Social Potency, Social Closeness, and Achievement) from the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982) that are closely aligned with the dimensions of the five-factor model that demonstrate significant relationships with leadership. Thus, based on this literature, we hypothesize that Social Potency, Social Closeness, and Achievement will demonstrate significant relationships with our leadership construct. Below we present more formal hypotheses concerning these personality variables and leadership construct.

1.3. Genetic basis for personality constructs

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. For example, 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.

Rowe (1994) summarizes his own earlier study (Loehlin & Rowe, 1992) in which multiple studies and samples that 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) were analyzed. The heritability estimates for the big five personality dimensions ranged from .39 to .49, with the heritability for Extraversion demonstrating the highest estimate (.49).

Moving beyond personality measures that rely on the Five Factor taxonomy, Tellegen et al. (1988) report a study using twins who were assessed on the 11 major personality traits as measured by the 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). Thus, we expect that the personality variables used in the present study will likewise demonstrate significant heritabilities.

1.4. Research hypotheses

Based on prior research and theorizing in leadership, personality, and behavioral genetics, the hypotheses associated with the present study are as follows: We predict that 1) there will be significant relationships between social potency, social closeness, achievement, and leadership role occupancy, 2) there will be a significant genetic influence on leadership role occupancy, 3) there will be significant genetic influences on social potency, social closeness, and achievement, 4) there will be an overlap between the genetic factors affecting personality and those affecting leadership role occupancy—i.e., positive correlations between the latent genetic factors on personality and on leadership role occupancy, and 5) genetic influences on the leadership measure will be realized through (or mediated by) the personality variables.

2. Method

2.1. Sample

The sample for this study was drawn from the Minnesota Twin Registry. The Registry is the product of an effort to locate 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. These twins were reared together rather than apart. 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 (1116 individuals) who participated in this earlier study. A total of 646 completed surveys were returned, yielding a response rate of 57.9%. 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 identical or monozygotic twins and 94 pairs were fraternal or 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, and 8% were divorced, separated, or widowed, and 14% were single. Other relevant characteristics of the total sample as well as 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 determination as to whether the twin pairs were identical or fraternal had been established previously 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 twin type (Lykken et al., 1990).

2.2. Measures

A variety of measures reflecting the different constructs were used. They are as follows:

Table 1
Sample characteristics

	Identical twin	Fraternal twin	Total
	$n = 331$	$n = 315$	$n = 646$
Age	$M = 36.71$, $SD = 1.13$	$M = 36.76$, $SD = 1.10$	$M = 36.73$, $SD = 1.12$
Occupation			
Managerial and administrative	20.7%	16.5%	18.6%
Professional, paraprofessional and technical	28.4%	24.7%	26.6%
Sales and related	11.1%	10.1%	10.6%
Clerical and administrative support	.6%	.6%	.6%
Service	6.9%	9.5%	8.2%
Agricultural, forestry, fisheries and related occupations	3.3%	6.0%	4.6%
Production, construction, operations, maintenance, and material handling	31.4%	37.3%	34.3%
Education			
High school	37.0%	38.8%	37.8%
Two-year college/vocational school	23.9%	26.1%	24.9%
B.A./B.S.	29.8%	25.0%	27.7%
M.A./M.B.A.	5.9%	4.8%	5.4%
Ph.D./J.D./M.D.	2.5%	3.2%	2.8%
Other	.4%	2.7%	1.4%

Note: Sample characteristics are based on individual twin rather than twin pair.

2.2.1. Leadership role occupancy

For the present research, we measured leadership from a role occupancy perspective where leadership is defined and measured in terms of the various formal and informal leadership role attainments of individuals in work settings. This perspective has been shared by other researchers. For example, Bass (1990) classified studies examining the personal characteristics associated with leadership when leaders were identified as "persons occupying positions of leadership" (p. 59). Bass (1990) further comments that people in such role positions "lead as a consequence of their status—the power of the position they occupy" (p. 19). Judge et al. (2002, p. 770) explicitly coded leadership studies that used positional components (e.g., held a position of leadership in high school compared to others that did not) as reflective of leadership emergence. More recently, Day, Sin and Chen (2004) used "Team Captain" of a hockey team as indicative of leadership role occupancy and studied the impact of role occupancy on later individual performance. We note that we are not attempting to measure leadership effectiveness in this study, which is a distinctly different construct that reflects how well individuals perform once in a leadership role. Ilies, Gerhardt, and Le (in press) make the point that leadership emergence is the "first step" in the leadership process and "thus its genetic underpinnings should be investigated first (i.e. first investigate what type of person becomes a leader and then examine who performs better as a leader)" (p. 5). In addition, we want to make explicit that simply because an individual occupied such positional roles, it does not necessarily mean that others will perceive or believe that he/she is indeed a leader.

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. These types of bio-history items have been used previously to assess leadership. For example, Mumford, O'Conner, Clifton, Connelly and Zaccaro (1993) reported a study where such items as "How many of the following leadership positions did you hold?" were used to develop a criterion measure of leadership. Similar type items are reported by Stricker and Rock (1998) to assess leadership potential [e.g. "How many times were you an officer (president, manager, etc.) of a club, team, or other organization in school, or elsewhere, when you were in high school?]. Chan and Drasgow (2001) used self-report biographical items (e.g. number of years as a class or school leader, level of seniority in high school extracurricular activities) as measures of past leadership experience.

There is also evidence that bio-graphically based measures are unlikely to be falsified presumably because much of the information can be verified. Substantial agreement has been found between what employees say compared to that found in actual records (r's ranging from .90 to .98) indicating that there is little falsification of bio-graphically based measures (Cascio, 1991, p. 265).

Respondents in our study replied to two items: 1) List the work-related professional associations in which they served as a leader (M=2.23, SD=.58), and 2) 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 two items.

Chi-square analyses revealed that the identical twins had held significantly more work group and director leadership positions on the job ($p<.05$) than the fraternal twins. No other differences were observed.

We developed two initial scores for each individual. The score of the second item 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. The contents of the "Other" category were manually reviewed and assigned points according to the above scoring method. This scoring method has been used previously (Flemming, 1935). The score on the first item was developed based on the number of leadership roles assumed in work-related professional associations. We standardized these two scores and then averaged them to create a leadership role occupancy composite. We had no a priori justification for providing differential weights for the two scores. We argue that this composite represents one form of a multidimensional construct—the aggregate model discussed by Law, Wong, and Mobley (1998).[1] According to this model a composite variable is formed by algebraically summing a number of other variables conceptually related to the construct of interest. The variables do not necessarily need to be statistically interrelated nor does the resulting composite necessarily represent an underlying latent construct.

[1] 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)).

Table 2
Responses on bio-history leadership role occupancy items

	Identical twin	Fraternal twin	Total
	$n=331$	$n=315$	$n=646$
Number of professional associations where you played a leadership 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	.6%	.6%	.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%
Composite leadership role occupancy measure	$M=.08$	$M=-.08$	$M=.00$
	$SD=.78$	$SD=.73$	$SD=.76$

Note: * Chi-square analysis showed significant difference in percentage between identical and fraternal twins at $p<.05$ level.
The comparisons are based on individual twin rather than twin pair.

One estimate of the reliability of this composite was developed using factor analytic procedures. The scale was factored along with 31 other variables that were not used in the present analyses (e.g. attitudinal items, income, etc.). The resulting communality value for this variable represents a conservative estimate of the lower bound of the reliability coefficient [see Harmon (1967), p. 19 and Wanous and Hudy (2001)]. The reliability estimate obtained was .55. The mean for this composite scale was .00 (SD=.76, $n=646$) with a range between −.67 to 4.52. There was a significant mean difference ($t=2.65$, $p<.01$) between identical twins ($m=.08$) and fraternal twins ($m=-.08$), but the effect size was relatively small between these two groups ($d=.21$).

There was additional evidence for the construct validity of this leadership composite measure:

1. The measure correlated significantly ($p<.01$) with scales formed using similar bio-history items where respondents reported their past leadership activities in high school (.14), college (.14), and in current community activities (.18).
2. The composite measure correlated against a "behavioral" measure completed also by the subjects and formed by developing a composite of three items drawn from the Steers and Braunstein (1976) Manifest Needs Questionnaire that constitute part of the dominance scale and are directly related to leadership. The three items were 1) "I seek an active role in the leadership of a group", 2) "I find myself organizing and directing the activities of others", and 3) "I strive to be 'in command' when I am working in a group". The alpha for this behavioral composite was .78 and it correlated significantly against the leadership role occupancy composite ($r=.33$, $p<.01$, $n=644$).
3. Subjects who indicated that they held managerial and administrative occupations had significantly higher leadership scores than individuals in other occupations[$t(158)=5.60$, $p<.001$], when the sample was classified into those holding managerial and administrative positions ($n=119$) versus all others ($n=527$).
4. The leadership role occupancy composite correlated ($r=.12$, $p<.01$, $n=636$) with total income as would be expected (Kuhn & Weinberger, 2002).
5. The measure was uncorrelated with a number of variables for which there were no a priori expectations of a relationship (e.g. marital status).
6. The scale was negatively related to variables for which a reverse relationship was expected [e.g., self-report on adjectives such as "procrastinator" ($r=-.09$, $p<.05$)].

7. The construct validity of a measure may also be inferred if it demonstrates the predicted relationships with a number of other variables in a nomological network (Arvey, 1992). As will be demonstrated in our Results section, our specified model, including this leadership variable, fits particularly well, allowing the partial inference of the construct validity of the measure.

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 composite 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, we believe there was sufficient specific information provided by the individuals about their leadership roles for us to infer that the information provided was accurate.

2.2.2. Personality measures

The 198-item form of the 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 in the present study regarding the leadership measures described above, reducing same-time method bias.

As mentioned in the introduction, the trait scales based on the MPQ scales have demonstrated relatively high heritabilities based on other samples. 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 MPQ Social Potency scale corresponds well with the lower-order dominance trait dimension of the Big Five that Judge et al. (2002) showed to have 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. Finally, the MPQ Social Closeness scale empirically maps onto the Extraversion 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 among these three MPQ scales ranged between −.07 and .35 and thus were relatively independent of each other. Based on these previous findings, we hypothesize these three MPQ scales to be significantly correlated against our measure of leadership role occupancy.

We recognize the potential issue that relationships between our posited independent and dependent variables could be a result of common method variance due to the same persons completing portions of the two sets of variables (Podsakoff, MacKenzie, Lee & Podsakoff, 2003). However, we argue this bias may be relatively low because of the following factors: 1) There was a considerable time difference between the completion of this personality inventory and the leadership survey (six years). This time span 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, and 2) If bias due to the same subject completing the personality and leadership measures was prominent, positive correlations would be exhibited across a majority of the personality scales with the leadership variable. Such was not the case (see Results below). Thus, our data collection methods follow many of the recommendations provided by Podsakoff et al. (2003, p. 887–888) to minimize such potential biases.

Lindell and Whitney (2001) proposed an approach to assessing and adjusting for common method variance. Their approach was used to estimate the relationships between our leadership measure and the two personality variables after making adjustments for possible bias due to common method variance. No bias was observed.[2]

[2] Lindell and Whitney (2001) propose that estimated correlations be adjusted for bias due to common method through the use of a "marker variable" that is theoretically unrelated to the predictor or criterion. In this approach, ideally the marker variable is identified prior to data collection and included in the survey. The Lindell and Whitney paper appeared after the data collection for our article. Thus, we did not build the marker variable into the survey. However, we collected demographic information, which includes variables that are theoretically unrelated to leadership or personality (e.g., education, size of community in which the participants live). We applied Lindell and Whitney's adjustment to the estimated correlation between leadership and achievement ($r = .16$) and leadership and social potency ($r = .23$) and found that the estimated correlations did not change significantly after the adjustment (i.e., $r = 0.17$ for leadership and achievement; $r = 0.23$ for leadership and social potency) using large city as the marker variable. This adjustment presents a slightly modified application of the adjustment proposed by Lindell and Whitney.

2.3. Analytical approach

As a first step in the analyses we correlated the three personality variables against the leadership variable. The second step in our analyses was to estimate the proportion of variance in the various measures due to genetic and environmental components. The multi-group confirmatory structural equation modeling (SEM) approach we used was the standard behavioral genetics methods of examining the degree of similarity or covariances of the individual twins on particular measures of interest (Plomin et al., 2001). If there is some genetic influence, identical twins should be more similar than fraternal twins after controlling for other variables.

We estimated the genetic influences (as well as the influences of shared and non-shared environmental factors) associated with each of the personality and leadership variables. The method of maximum likelihood as operationalized in the software program *Mx* (Neale, 1994) and *LISREL* (Jöreskog & Sörbom, 1993) was used (See Appendix B for details of the analyses).

First, we examined the heritability of the leadership and personality variables one at a time (i.e., univariate analysis). The basic univariate model for twin data includes three factors that influence an observed measurement or phenotype: genetic effects (A), common environmental effects (C), and non-shared environmental effects and/or error (E). The C factor refers to influences shared by members of the same family (e.g. income level, number of books in the home, parental warmth, same high school, etc—those features of the environment shared by each twin). As shown in Eq. (1), variance in the leadership measure is expressed as the sum of variance attributable to each of the three factors, A, C, and E, each weighted by a path coefficient (a, c, and e) that determines their relative influence:

$$\mathrm{Var}_{\text{leadership}} = a^2 + c^2 + e^2 \tag{1}$$

The heritability is defined as the proportion of total variance that is associated with genetic factors: $h^2 = a^2 / \mathrm{Var}_{\text{leadership}}$.

Fig. 2 presents the confirmatory structural model used to describe the relationships among the variables for two individuals who are either identical or fraternal twins. This is the established SEM model used for behavioral genetics research (e.g., Heath, Neale, Hewitt, Eaves & Fulker, 1989). Appendix B provides the detailed steps in estimating the two-group structural equation models.

Identical twins share all their genetic material, thus the correlation coefficient is 1.0 between the genetic component of Twin 1 and Twin 2 of the identical twin pair. Fraternal twins share, on average, one half of their genes so that the corresponding correlation is .5 for the fraternal twins. The correlation between common environment between pair members of both twin types is set at 1.0, reflecting the assumption of equal common environmental

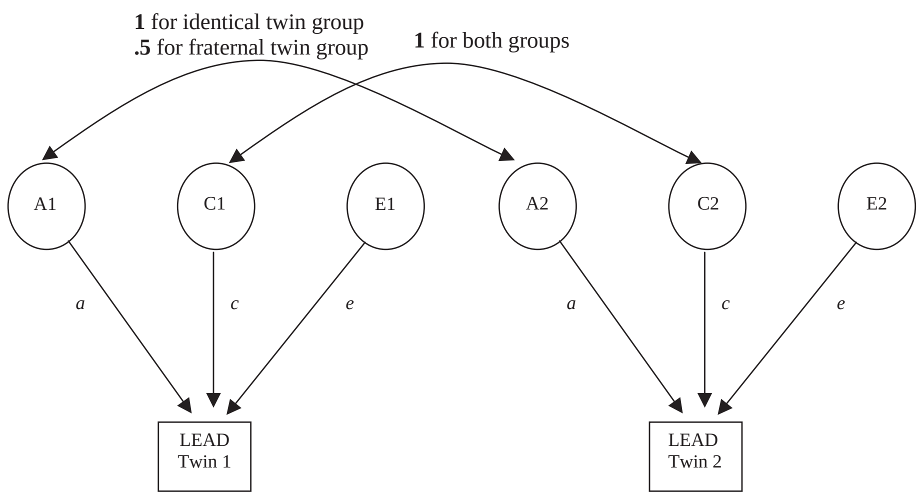

Fig. 2. Multigroup SEM analyses on the univariate genetic model. A, C, and E represent additive genetic factor, shared environmental factor, and non-shared environmental factor, respectively. Paths with the same label are constrained to be equal across groups. Subscripts 1 and 2 represent the first and second twin within a pair.

influence, whereas the path between the non-shared environmental factors for the twins is, by definition, specified as zero. Following the practice of behavioral genetic research using this model, we also test differences in model specification where a full model (with A, C, and E factors all present) is tested against alternative nested models—(only A, E factors), (only C, E factors), (only E)—to determine the significance of the corresponding path coefficients. If, for example, the path coefficient *c* is not significant, the A,E model will show little Chi-square change and would probably have better fit indexes than the full A,C,E model.

Second, multivariate SEM models were used that are the direct generalizations of the univariate ones. These models allow us to estimate the extent to which two variables share common genetic influences (i.e., testing the significance of the genetic correlation). In addition, using multivariate models we can control for the various personality variables when estimating genetic influence on leadership measure and we can also estimate simultaneously the A, C, E factors of all the personality variables. The difference between these two types of models is analogous to that between simple regression and multivariate regression.

Finally, we used the multivariate SEM model to test the proposed mediated relationships between genetic factor and leadership role occupancy. This SEM approach can overcome the limitations of the Baron and Kennys (1986) regression-based technique and is recommended by Bing, Davidson, LeBreton and LeBreton (2002). In particular, using LISREL programs (Jöreskog & Sörbom, 1993), we test whether the relationship between the genetic factor and leadership variable is mediated by the personality variables. Fig. 3 provides the schematic diagrams that illustrate the three alternative models testing mediation effects.

3. Results

3.1. Correlations

Hypothesis 1 predicted significant relationships among social potency, social closeness, achievement, and leadership role occupancy. The zero-order correlations of the various personality and leadership variables are shown in Table 3. The leadership variable is significantly correlated with all three of the personality variables as hypothesized. The MPQ scale of Social Potency showed the highest correlation (.23, $p<.01$) whereas the Social Closeness scale showed the lowest (.10, $p<.05$). The multiple regression coefficients 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.

While not shown in Table 3, a number of MPQ personality dimensions failed to show a significant correlation with the leadership measure (i.e., Stress Reactivity, Alienation, Aggression, Control, Harm Avoidance, Traditionalism, and Absorption). If the observed relationships between the MPQ scales (i.e., social potency and achievement) predicted to be related to the leadership variable were due to common method variance, these other MPQ scales (e.g., Aggression, Control) would likewise show significant relationships. Such was not the case, providing additional evidence that the observed relationships posited between them and the leadership variable were more likely due to true relationships between the variables rather than common method bias. Thus, Hypothesis 1 was supported.

3.2. Univariate multi-group SEM analyses

Hypotheses 2 and 3 predicted a significant genetic influence on leadership role occupancy and the two personality variables. Table 4 shows the results of univariate structural equation analyses to determine the best-fitting model from alternative nested models for each of the variables.

Five criterion indexes were chosen to evaluate the model fits. The indexes selected were the traditional chi-square (χ^2) test, Akaike's Information Criterion (AIC; Akaike, 1983), Steigers (1990) root mean square error of approximation (RMSEA), Incremental fit index (IFI), and Bentler (1990) comparative fit index (CFI). In addition, the 90% confidence intervals of RMSEA and the power for test of model fit based on RMSEA were also reported when available.

The Root Mean Square Error of Approximation (RMSEA) represents an advance in the evaluation of model fit from both a statistical and a conceptual viewpoint. Browne and Cudeck (1993) argue that because theoretical models are at best approximations of reality, the null hypothesis for any measurement/structural equation model (i.e., the conventional chi-square test that the data fits the model perfectly) will rarely be true. Rather than testing the null

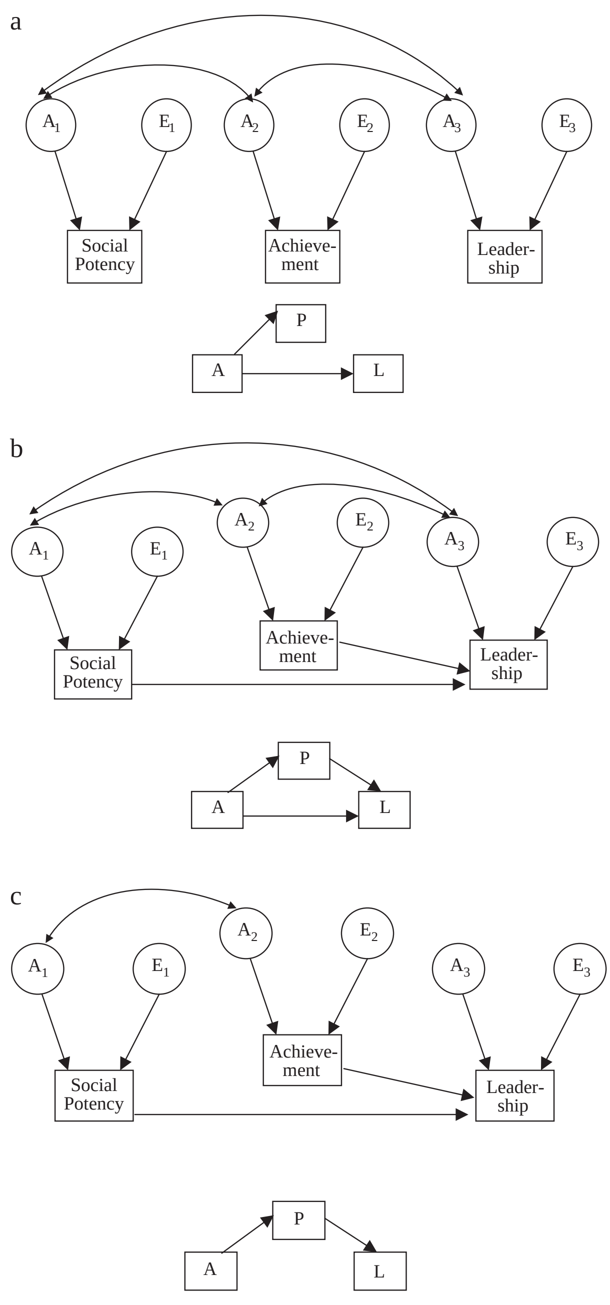

Fig. 3. Test of mediating effects of Social Potency and Achievement on the Genetic Influences on Leadership Role Occupancy (for one twin). a, b, c: A and E represent the additive genetic component and non-shared environmental component for Social Potency, Achievement, or Leadership Role Occupancy. Only the mediation pathways for one twin in a given pair are illustrated. The other twin has the same configuration and the identical and fraternal groups are simultaneously estimated. An analogical conceptual graph is shown below each model.

hypothesis of *exact fit* between the covariance matrix of a sample and the model for the population, RMSEA establishes a hypothesis of *close fit* between the model and population. RMSEA values of .05 or less indicate a very close fit between sample and theoretical model, accounting for degrees of freedom. Values less than .08 reflect reasonably well fitting models (Browne & Cudeck, 1993).

In SEM, if a model is "accepted" based on a fit index such as RMSEA, we need to examine whether it is because the alternative model is wrong or because the study design makes it unlikely that the potential misfit would be detected. Statistical power is the probability of obtaining a statistically significant result given that the alternative hypothesis

Table 3
Means, standard deviations, and zero-order correlations of personality and leadership measures

	n	Mean	*SD*	1	2	3
1 Social potency	533	49.28	9.89			
2 Achievement	533	49.22	9.91	.25***		
3 Social closeness	533	49.03	9.91	.35***	−.07	
4 Leadership role occupancy	646	0.00	.76	.23***	.17***	.10*

Note: *$p<.05$, **$p<.01$, ***$p<.001$ (two-tailed).
Correlations among variables are at the individual twin level. This matrix is not the input matrix for the multi-group confirmatory SEM analysis. The actually input matrices are the variance/covariance matrices of twin 1 and twin 2 variables for each of the two groups (see Appendix B).

is true. Sample size will determine the power of the statistical test. With small sample sizes (and low power) we may have difficulty rejecting incorrect models, whereas with large sample sizes (and high power) we may find that no model fits well. In the present study, the power of the test of model fit is calculated using an adapted version of a SAS program written by MacCallum, Browne, and Sugawara (1996). It should be noted that if we reject the null hypothesis that the model has a good fit, there is no need to report the power estimates. See Appendix C for details.

The results from the univariate analyses indicate that the power for test of fit based on RMSEA is relatively low for most of the models due to the small sample size. Thus, we focused on a variety of model fit indexes to determine the model fit, such as Chi-square statistic, AIC, IFI, and CFI, in addition to RMSEA. Using these various criteria, the A,E model (i.e., the genetic and non-shared environmental model) was the best-fitting model for each of the two personality variables and the leadership variable. This result indicates that the shared-environment had little influence on the personality and leadership measure.

In particular, while the full A,C,E models exhibit quite similar fit indexes as did the A,E models, the latter was chosen as the best-fitting model because the it has greater parsimony and relatively better fit. As indicated in Table 4, models that failed to include the genetic factor produced a poor fit. The univariate A,E model fit particularly well for the leadership role occupancy variable in terms of the five fit indexes—the chi-square statistic was not significant, the RMSEA was .00 with the 90% confidence interval of (.00, .14), the AIC value was negative, and the IFI and CFI were

Table 4
Results of univariate model-fitting for leadership role occupancy, social potency, and achievement

	Sample size (identical/ fraternal pairs)	Model fit indexes								
		χ^2	*df*	$\Delta\chi^2$	Δdf	RMSEA (90% CI)	Power for test of close fit	AIC	IFI	CFI
Leadership role occupancy	119/94									
A,C,E		3.73	3	n/a	n/a	.02 (.00, .18)	.31	−2.27	1.02	1.00
A,E[@]		3.73	4	0.0	1	.00 (.00, .14)	.41	−4.27	1.12	1.00
C,E		8.50	4	4.77*	1	.10 (.00, .22)	n/a	0.50	.67	.75
E		17.90**	5	14.2**	2	.29 (.16, .46)	n/a	7.90	−.22	.13
Social potency	106/69									
A,C,E		3.36	3	n/a	n/a	.03 (.00, .19)	.26	−2.64	1.02	1.00
A,E[@]		3.36	4	0.0	1	.01 (.00, .11)	.40	−4.64	1.04	1.00
C,E		11.8*	4	8.44**	1	.14 (.02, .25)	n/a	3.79	.82	.83
E		54.9**	5	51.5**	2	.28 (.21, .35)	n/a	44.9	−.33	.00
Achievement	106/69									
A,C,E		2.49	3	n/a	n/a	.02 (.00, .17)	.31	−3.51	1.07	1.00
A,E[@]		2.49	4	0.0	1	.00 (.00, .09)	.41	−5.51	1.12	1.00
C,E		8.37	4	5.88*	1	.10 (.00, .21)	n/a	0.37	.84	.86
E		30.2**	5	27.7**	2	.20 (.13, .27)	n/a	20.2	−.24	.00

Note: *$p<.05$, **$p<.01$; [@] indicates the best-fitting model.
A, C, and E represent additive genetic factor, shared environmental factor, and non-shared environmental factor, respectively. The full names of the fit indexes are Akaike's Information Criterion (AIC), Root Mean Square Error of Approximation (RMSEA), Incremental Fit Index (IFI), and Comparative Fit Index (CFI).
Power estimates for test of fit are provided only for the model that we failed to reject the null hypothesis. If we already reject a model, there is no need to report power.
Degree of freedom was calculated as the total number of sample moments (3 for each group) minus the number of distinct parameters.

both no less than 1.00. There is good evidence of genetic influence for this observed leadership role occupancy variable. The A,E model was also the best-fitting model for Social Potency and Achievement. Thus, Hypotheses 2 and 3 were supported.

While not shown in Table 4, the estimate of the proportion of variance for the genetic factor (i.e., heritability estimate) under the univariate A,E model for leadership was .31 (confidence intervals of .15 and .45), whereas the estimate for the non-shared environmental factor was .69 (confidence interval of .55 and .85). The corresponding estimates for the genetic factor for the Social Potency variable were .54 and .42 for the Achievement variable (the confidence region for these two variables excluded zero).

3.3. Multivariate multi-group SEM analyses

Multivariable analyses allow us to estimate the genetic influence on leadership role occupancy while controlling for the two personality variables. In addition, the correlations among the genetic factors on personality and leadership variables can be estimated based on the multivariate model. Similar to the procedures in the univariate analyses, several alternative models (A,C,E vs. A,E vs. C,E vs. E) were tested and compared to determine path coefficients' significance and to find the best-fitting model. The A,E model is chosen based on fit indexes such as Chi-square, RMSEA, AIC, IFI. The full A,C,E model performs worse than the A,E model. For example, the full model has RMSEA of .15 with 90% CI of (.07, .23), IFI of .93, and CFI of .92 whereas the A,E model has RMSEA of .07 with 90% CI of (.00, .13), IFI of .96, and CFI of .96. These results further showed that share environmental factors did not have significant impact on the personality and leadership variables. The results are in line with the findings from other studies on personality. For example, Eaves, Eysenck, and Martin (1989), in their study on genes, culture, and personality, showed that the shared environments account for a very small percent of the total variance of a variety of personality variables. Loehlin and Nichols (1976), as well as Tellegen et al. (1988), have similar findings. The implications of this result are discussed in the Discussion section.

Table 5 presents the heritability estimates based on the best-fitting multivariate A,E model. We estimate that the genetic factor (A) accounted for 30% of the variance (95% confidence interval .14–.44) for the leadership variable after controlling for the two personality variables, whereas the non-shared environmental and/or measurement error factor accounted for the remaining proportion of the variance (.70). As would be expected, these results largely replicate those obtained using the univariate analyses, providing additional support for Hypothesis 2.

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. These results provide additional support for Hypothesis 3 that there would be a significant genetic component to the personality variables.

Hypothesis 4 predicted that some of the genetic factors that affect personality would be shared with the genetic factors that affect the leadership variable. As shown in Table 5, the structural equation analyses also generated the genetic correlations between the various personality variables and the leadership variable. 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

Table 5
Results of multivariate model-fitting for social potency, achievement, and leadership role occupancy

	Proportion of variance due to			Genetic correlation b/w personality variables and leadership
	Genetic (h^2)	Shared environment	Non-shared environment	
Best-fitting (A,E) model				
Social potency	.54 (.41, .65)	n/a	.46 (.35, .59)	.49 (.21, .79)
Achievement	.43 (.27, .56)	n/a	.57 (.44, .73)	.65 (.32, .98)
Leadership role occupancy	.30 (.14, .44)	n/a	.70 (.57, .86)	n/a

Note: 95% confidence intervals in parentheses.
This model is based on raw data rather than covariance matrix. The sample sizes vary across variables. For Leadership Role Occupancy the sample size is 119/94 pairs for identical/fraternal twins, while for Social Potency and Achievement it is 106/69 pairs. The missing data are treated as missing completely at random.

can be explained by the genetic factors affecting each of the personality factors. To illustrate the concept of genetic correlation, consider two completely heritable traits such as eye and hair color. Though heritability is 100% for each separately, 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.

The results 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 was .49 (with 95% confidence interval excluding zero), indicating that 24% 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 .65 (95% confidence interval excludes zero), indicating that 42% of the genetic variance for leadership is shared with this personality factor. Thus, Hypothesis 4 is supported.

While not shown in Table 5, the correlations between non-shared environmental factors are not significant: .03 for Social Potency and Leadership, and −.06 for Achievement and Leadership, respectively. The 95% confidence intervals both include zero.

3.4. Test of mediation effects

We continued to test the hypothesis that the genetic influences on leadership are mediated by the two personality variables (Hypothesis 5). Fig. 3a, b, and c provide an illustration of the different paths that are estimated freely or fixed to zero. For clarification purpose, a highly simplified analogous model was provided for each of the models in Fig. 3. Table 6 shows the fit indexes for these alternative models. Note that the test of mediation was based on the multivariate A,E model rather than the A,C,E model because in both the univariate and the multivariate analyses we already established that the shared common environment have no significant impact on the personality and leadership variables. In addition, the mediation tests based on A,C,E model gave significantly poor model fit indices and thus are not reported in Table 6.

In the "fully" mediating model (Fig. 3c), two mediation pathways between Social Potency and Achievement and Leadership Role Occupancy were estimated and the pathways representing typical genetic correlations are fixed at zero. This model and the no-mediation model (i.e., classic behavioral genetic model as in Fig. 3a, where the mediation pathways between the personality and the leadership variables are fixed at zero while genetic correlation pathways are estimated) were compared to a partial mediation model (Fig. 3b, where the mediation pathways and genetic correlation pathways are all estimated). The partial mediation model is the statistically "full" model whereas the other two are the "nested" models. For simplicity, graphs in Fig. 3 provide only a conceptual diagram for one twin in each group.

As indicated in Table 6, the A,E without mediation model (3a) showed a better fit than the alternative models. For example, model 3a has the AIC of 42.8, a RMSEA of .071, IFI of .96, and CFI of .96, as compared to

Table 6
Test of mediating effects of personality variables on the genetic influence on leadership role occupancy

Model	χ^2	*df*	$\Delta\chi^2$	Δdf	RMSEA (90% CI)	AIC	IFI	CFI
A,E model with partial mediation (Fig. 3b)	17.7*	9	n/a	n/a	.09 (.00, .16)	46.8	.95	.94
A,E model with full mediation (Fig. 3c)	28.3**	13	10.6*	4	.11 (.05, .16)	50.6	.91	.90
A,E model without mediation (Fig. 3a, best-fitting)	17.7	11	0.0	2	.07[a] (.00, .13)	42.8	.96	.96

Note: $^*p<0.05$, $^{**}p<0.01$.
A and E represent additive genetic factor and non-shared environmental factor, respectively.
The full names of the fit indexes are Akaike's Information Criterion (AIC), Root Mean Square Error of Approximation (RMSEA), Incremental Fit Index (IFI), and Comparative Fit Index (CFI).
The sample sizes vary across variables. For Leadership Role Occupancy the sample size is 119/94 pairs for identical/fraternal twins, while for Social Potency and Achievement the sample size is 106/69 pairs.
Degree of freedom was calculated as the total number of sample moments (42−18=24) minus the number of distinct parameters. Note that we adjusted the degree of freedom by −18 since we double-entered the twin data in order to get rid of the sequence effect. Sequence effect refers to the effect on covariance matrix by the sequence in which each twin enters the analysis as first or second twin within a pair.
[a] Power for test of close fit using RMSEA is .34.

corresponding values of 50.6, .11, .91, and .90 for A,E full mediation model (3c). However, the A,E partial mediation model (statistically "full" model) is not significantly better than the A,E without mediation model, and the chi-square change test was not significant. In other words, we cannot empirically distinguish the partial mediation model and the no-mediation model in terms of fit indexes. In contrast, the fully mediating model 3c was rejected, which means the genetic effect on leadership role occupancy was not realized solely through the two personality variables.

This inability to distinguish between partial mediation model and no-mediation model may be due to the low power of the test. In particular, due to small sample sizes, the power for test of model fit using RMSEA is only .10 for the best-fitting model. It could be that our sample of around 100 pairs in each group is too small to detect possible lack of fit of a model. However, the fact that we did reject the full mediation model indicates the statistical power for testing of model fit in this situation is not far out of the reasonable range.

In sum, we cannot make definitive conclusions on whether there is a partial mediating effect of Social Potency and Achievement variables carrying the genetic effects through to leadership. The no-mediation model and the partial mediation model do not differ significantly in terms of the fit indexes. Thus, hypothesis 5 is not supported here.[3] However, the A,E partial mediation model provides very similar estimates of the genetic and non-shared environmental influences and their heritability estimates to those provided by the A,E no-mediation model. Thus the findings in the Multivariate Analyses section and the estimates in Table 5 still hold.

4. Discussion

In this study, we were interested in examining the role of genetic influences in predicting leadership role occupancy and different personality variables as well as any observed covariation among them. This research offered new evidence in this arena. Findings clearly indicated that genetic factors influence the personality and leadership variables and confirmed earlier research showing that personality constructs have strong genetic influences.

Of perhaps most interest in this study is the finding that the leadership role occupancy variable had an estimated heritability of .30 based on the multivariate model, meaning that 30% of the variance in this variable was accounted for by genetic factors. Non-shared environmental influences still accounted for 70% of the variance. However, in the context of leadership research, it is difficult to find other variables that would account for this much variance. For example, in a recent article, Judge, Colbert, and Ilies (2004) report the results of a meta-analysis of the relationship between intelligence and leadership. The corrected correlation was .27, which, when squared, accounts for 7% of the variance. In addition, as reported in our introduction, personality constructs generally show significant correlations with leadership, but the proportion of variance explained does not exceed 10%. Within this context, then, genetic influences of 30% of variance are quite powerful. We note here, however, that we are not suggesting that we have information concerning precise gene structures that would allow such predictions.

Our findings can be well integrated into other "trait" theories of leadership where individual differences are shown to be predictive of leadership. For example, our findings are to some degree consistent with the earlier research of Kenny and Zaccaro (1983) wherein they found that 49–82% of the variance in leader emergence was attributed to characteristics of the leader and while genetic factors do not explain this amount of variance, they represent some portion. In addition, the findings that the two personality variables are related to the leadership constructs add more evidence for the role of these constructs within the "trait" leadership framework.

The results also revealed that some of the genetic factors that influence leadership are the same or similar to the genetic factors influencing personality 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 measures, suggesting that this leadership role occupancy variable has other independent genetic influences as well.

[3] Our research interests lie in the comparisons between both Fig. 3c and a and the baseline model Fig. 3b. We conclude that "there was no definitive evidence whether these personality variables partially mediated the relationship between genetic factors and leadership". In other words, model 3b and model 3a are not significantly different. We cannot ascertain whether partial mediation exists, but we did show that full mediation model 3c had a poor fit. We did not directly compare model 3c with model 3a. They are non-nested models and cannot be compared in terms of Chi-square difference. However, they are still comparable using fit indexes such as AIC and RMSEA or by looking at the significance levels of specific path coefficients.

It is also important to underscore that while genetic influences account for a sizable portion of leadership variance, environmental factors are substantially important in determining leadership. From a practical perspective, what might be 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 an individual's development (McGue, Bouchard, Iacono, & Lykken, 1993).

Furthermore, the large amount of variance explained by environmental factors suggests malleability among individuals with regard to external factors in developing and "producing" leaders—at least in terms of leadership role occupancy. Thus, to some extent individuals might be predisposed to engage in leadership behaviors that would propel them into leadership roles based on their genetic influences. However, individuals who are not so predisposed may still move into leadership roles if exposed to environmental factors that develop leadership.

As we explained earlier, while we do not know exactly what these environmental factors are, future research can focus on identifying these factors. For example, training in leadership is one factor that should be examined. Thus far if one is trying to predict who will move into leadership roles one clue would be to examine one's past history of assuming leadership roles. If our findings are accurate, one might expect some stability in leadership role occupancy for individuals across time (e.g., college, high school, etc.). In organizational contexts, interviewers would be looking for patterns of past leadership roles among individuals—something that many interviewers probably do when selecting leaders. We should note that 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).

Of some surprise is the finding that the "shared environment" factor did not appear to be a significant factor in influencing leadership (as well as personality variables). These results are consistent with research in other areas of behavioral genetics (e.g., Eaves, Eysenck, & Martin, 1989; Loehlin & Nichols, 1976; Tellegen et al., 1988). The main line of thinking about this is not that families have no influence but rather it is individualized rather than common. That is, each twin has a special and unique relationship with each parent (and even his/her own twin) and this is captured in the "non-shared environment" factor. As a consequence "shared environments" such as SES and common educational experiences (e.g., same grade and high school, etc.) just don't seem to matter.

Although the personality and leadership variables demonstrated significant heritabilities and common genetic influences, we lack the evidence and cannot conclude that the two personality variables partially mediate the genetic influences. However, there could be other unexamined variables (e.g. cognitive variables, physical characteristics) that could demonstrate such a mediating role.

4.1. Limitations

There are a number of potential issues and/or limitations with this study that need to be recognized. The first is the issue of whether the measure of leadership we utilized is 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 was 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. Future research should certainly 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 426 subjects (119 pairs of identical twins and 94 pairs of fraternal twins) were used in the present study, this is not a large sample given the nature of the modeling methods used, which typically requires fairly large sample sizes to develop precise point estimates and confidence intervals. In consequence, for most of the confirmatory structural models in this study the power estimates for test of fit based on RMSEA are less than 0.50. In other words, the failure to reject the model based on SEM fit indexes could be due to the low power to detect possible lack of fit of the model using a sample of current size. A larger sample would allow a more accurate test of the models. However, one indication that the power of the statistical tests of these models is reasonable is that we did reject some models. For instance, we rejected the A,E full mediation model in the test of mediation effects (see Table 6). Replication of this research across large 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.

It is also important to recognize that the estimates for genetic influence obtained here were sample-specific. Future research might take several forms. First, replication is needed with different samples and measures. For example, exploring the genetic influences on leadership among a female sample would be interesting and informative. Second, research exploring the possible interactions between genetic and environmental components could be very informative in terms of what kinds of interventions could be useful in accelerating leadership development as well as identifying which kinds of environmental conditions make “a difference” along with genetic factors in influencing leadership.

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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

Appendix B. Multi-sample confirmatory structural models used in this study

B.1. Univariate analysis

The two-group confirmatory structural model is illustrated in Fig. 2. The path coefficients (a, c, and e) represent the relative influences of the additive genetic, shared environmental, and non-shared environmental latent variables on the observed leadership variable.

All the path coefficients and factor correlations are restrained to be equal across the two groups except for the correlation between the two A-factors within a pair. The correlation between the two A's are fixed at 1 for identical twins because they have exactly the same genetic makeup. The corresponding correlation in fraternal twin group is set to be 0.5 because genetic research showed that, *on average*, fraternal twins are like siblings sharing only 50% of their genetic materials. The correlations between the C-factors are set at 1 for both groups because by definition both types of twins share a common environment. In contrast, the correlations between the E-factors are set at 0 for both groups because they are individual-specific and non-shared with the other twin.

Mx software (Neale, 1994) was used in our analyses. The analyses are identical to those commonly carried out in AMOS 5 or LISREL. We used the multi-sample SEM feature in Mx to estimate the identical twin and fraternal twin groups simultaneously. The level of confirmatory structural equation modeling analysis is the twin pair. Thus the sample sizes are based on the number of twin pairs in each group. The inputs for the two groups are the variance/covariance matrices of twin 1 and twin 2 traits within identical and fraternal twin pairs, respectively:

$$\begin{bmatrix} \mathrm{Var}(X_{\mathrm{twin1}}) & \\ \mathrm{Cov}(X_{\mathrm{twin1}}X_{\mathrm{twin2}}) & \mathrm{Var}(X_{\mathrm{twin2}}) \end{bmatrix}$$

B.2. Multivariate analysis

In multivariate analysis, there are three observed variables for each twin in each group, Social Potency (SP), Achievement (AC), and Leadership Role Occupancy. Each variable is influenced by its specific A, C, and E factors. As in the univariate analysis, for each variable, the A-factors are correlated at 1 between identical twins, but at 0.5 between fraternal twins. By definition, the shared environmental (C) and non-shared environmental (E) factors are correlated at 1 and 0 for both groups, respectively.

In both groups the correlations between the A factors (and also, between the C factors or E factors) on different variables are to be estimated. These correlations are set equal for both twins and across groups. Of interest are the correlations among the genetic factors for these variables. These genetic correlations reflect the overlaps among the genetic influences on the three observed variables.

The input data to the program are the 6 by 6 variance/covariance matrices for each group. The variables included in the matrices are, in a specific order, SP_{twin1}, AC_{twin1}, $Lead_{twin1}$, SP_{twin2}, AC_{twin2}, and $Lead_{twin2}$.

All SEM syntaxes are available from the first author on request.

Appendix C. Power estimation for testing of model fit

Statistical power is the probability of obtaining a statistically significant result given that there is a real effect in the population being studied (Cohen, 1988). Sample size and effect size will determine the power of the statistical test. With small sample sizes we may have difficulty rejecting incorrect models, whereas with large sample sizes we may find that no model fits well (MacCallum et al., 1996).

The power for the test of close fit using RMSEA is calculated using a SAS program by MacCallum et al. (1996). Power is also reported by LISREL software as the "probability of RMSEA < .05". Since power estimates reveal the probability of detecting a poor fit given the degrees of freedom and sample size when the model is actually poorly fitted, there is no need to estimate power for already rejected models.

The following table compares the logic of power estimation for the one-sample t-test and the test of model close fit based on RMSEA. Effect size reflects the degree of deviation from H_0 that researchers consider important enough to warrant attention. Note that effect size refers to the underlying population rather than a specific sample.

	One-sample t-test	Structural equation model
Null hypothesis	$u=u_0$	Close fit with $RMSEA_0<.05$
Alternate hypothesis	$u>u_0$	Poor fit with $RMSEA_a \geq .08$
In fact, the alternative is true	$u=u_1$, $(u_1>u_0)$	Poor fit, e.g., $RMSEA_a=.10$
Indication of the effect size	$d=(u_1-u_0)/\sigma$	Function of $(RMSEA_a - RMSEA_0)$
Prob. of detecting this effect size given the sample size	Power of one-sample t-test	Power for testing of close fit

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