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Developmental and Genetic Determinants of Leadership Role Occupancy Among Women

Richard D. Arvey
University of Minnesota, Twin Cities Campus, and National University of Singapore Business School

Zhen Zhang
University of Minnesota, Twin Cities Campus

Bruce J. Avolio
University of Nebraska—Lincoln

Robert F. Krueger
University of Minnesota, Twin Cities Campus

The genetic and developmental influences on leadership role occupancy were investigated using a sample of 178 fraternal and 214 identical female twins. Two general developmental factors were identified, one involving formal work experiences and the other a family experiences factor hypothesized to influence whether women move into positions of leadership in organizations. Results indicated that 32% of the variance in leadership role occupancy was associated with heritability. The 2 developmental factors also showed significant correlations with leadership role occupancy. However, after genetic factors were partialed out, only the work experience factor was significantly related to leadership role occupancy. Results are discussed in terms of prior life events and experiences that may trigger leadership development and the limitations of this study.

Keywords: leadership development, genetic components of leadership, behavioral genetics

Prior research has adopted methods used by behavioral geneticists to assess the degree to which genetic factors play a role in constructs related to organizational behavior such as cognitive ability, personality, and work attitudes. Arvey and Bouchard (1994) and, more recently, Ilies, Arvey, and Bouchard (2006) provided comprehensive summaries of research supporting the proposition that genetic factors are important determinants of such work-related constructs.

Recent attention has turned to examining the degree to which genetic factors play a role in the determination of leadership in organizations. For example, Arvey, Rotundo, Johnson, Zhang, and McGue (2006) used a sample of male twins to estimate the degree to which genetic factors were associated with leadership role occupancy (i.e., the extent to which individuals had or were now occupying positions of formal leadership in organizational settings). Their findings revealed that 30% of the variance in leadership role occupancy could be accounted for by genetic factors, whereas nonshared (or noncommon) environmental factors accounted for the remaining variance in this construct. Nonshared environmental factors refer to differences in environmental contexts embedded in experiences over time that are unique to each twin (and thus nonshared).

Several issues surfaced in the Arvey et al. (2006) study that demand further investigation. First, there is a question concerning the relative generalizability of these findings to other populations and samples. For example, would the results generalize to a female sample? A second and perhaps more intriguing issue concerns developing a better understanding of the specific nonshared environmental variables that play more or less of a role in the determination of leadership. Arvey et al.'s study was silent on the issue of which environmental variables contributed to leadership role occupancy. That is, although it is clear that environmental and other developmental influences unique to specific individuals contributed to leadership role occupancy independent of the genetic factors, no further information in that study was provided concerning the type of environmental experiences that were more or less important in predicting leadership occupancy. It has been suggested that certain environmental factors may trigger development in individuals that may result in their emergence into leadership roles (Avolio & Luthans, 2006). Avolio (1999) referred to the "in vivo" life experiences unique to individuals that shape leadership development, emergence, and success. However, leadership research has yet to focus on the contribution of these experiences while taking into account genetics. This is an essential area to explore to the extent one adopts the notion, as suggested by Mumford, Stokes, and Owens (1990), that "hereditary and environmental influences often work in tandem" (p. 48) or, as noted by Riegel (1975), "human development can only be understood by conceiving the emergence of behavior over time as a result of an ongoing exchange between the organism and the environment" (p. 106).

Richard D. Arvey, Carlson School of Management, University of Minnesota, Twin Cities Campus, and National University of Singapore Business School, Singapore; Zhen Zhang, Department of Human Resources and Industrial Relations, Carlson School of Management, University of Minnesota, Twin Cities Campus; Bruce J. Avolio, College of Business, University of Nebraska—Lincoln; Robert F. Krueger, Department of Psychology, University of Minnesota, Twin Cities Campus.

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Correspondence concerning this article should be addressed to Richard D. Arvey, Department of Management and Organization, National University of Singapore Business School, Singapore 117592. E-mail: bizra@nus.edu.sg

Leadership Issues Among Women

Leadership among women is an important but perhaps poorly understood area of research. In terms of importance, we know, for example, that women are severely underrepresented in managerial and executive positions in organizations.

There are many possible explanations for the underrepresentation of female managers and executives, including access discrimination against women (the "glass ceiling"), work–family conflict, women themselves choosing not to pursue leadership positions, and fewer opportunities for women to engage in leadership development that promotes their ascendance into leadership roles (see Hewlett & Luce, 2005). To date, the kinds of personal characteristics among women that might predispose and direct them toward leadership roles as well as to "burst through" the glass ceilings have not been thoroughly explored.

Another possibility is that genetic factors may influence which women move into leadership roles and the kinds of leadership they attain. The notion that genetic or innate differences might be partially responsible for differences in achievement between men and women is a politically sensitive issue that has received a good deal of media attention. For example, the remarks by then president of Harvard University Lawrence Summers at a conference on diversifying the science and engineering workforce (Summers, 2005) on the possible genetic differences between males and females in their abilities related to achievement in the physical sciences provoked a storm of criticism and controversy (see Muller et al., 2005). In response to critics of Summers, Steven Pinker, author of *The Blank Slate* (Pinker, 2002), made the point that "to what degree these and other differences originate in biology must be determined by research, not fatwa" (Pinker, 2005, p. 1). Although we do not explore here the issue of whether genetic influences are responsible for the differences observed between men and women in their ascendance into leadership positions, we do ask the question of whether genetic influences among women could be responsible for differences observed in their movement into leadership roles.

As mentioned above, a recent study of the genetic influences on leadership was conducted by Arvey et al. (2006). This study used a twin methodology in which a sample of 650 identical and fraternal male twins self-reported their leadership roles and experiences. A biohistory approach was used in which each twin indicated the number and kinds of leadership roles they had held in various employment settings. Results showed that 30% of the variance in leadership role occupancy could be accounted for by genetic factors, whereas nonshared (or noncommon) environmental factors accounted for the remaining variance in leadership role occupancy. Arvey et al. found that the shared environmental factor (e.g., common influences from the twins' family) plays little role in explaining the variance of the leadership construct. The concept of "nonshared environmental factors" essentially includes all possible exogenous and personal events during one's lifetime that could influence leadership emergence, other than genetic effects and the influences shared by twins in a common family environment.

In sum, recent research linking leadership and genetics suggests two questions pertaining to the results: First, do the results generalize to other samples, specifically, to female samples? Second, because the data and results are essentially silent on the kinds and types of environmental influences that are associated with leadership, what are the specific environmental variables that contribute to leadership independently of genetic factors?

Environmental Influences

What kinds of environmental variables could influence leadership emergence and development? This question has been asked and researched for years and includes a broad range of experiences that could impact whether a person moves into leadership roles (Avolio, 2005). In our current study, we identified a number of specific experiences that could represent developmental influences for investigation on the basis of prior literatures. These include the following:

1. Educational experiences: Evidence for past educational experiences being related to future managerial success was provided by Bray, Campbell, and Grant (1974), Howard (1986), and Wakabayashi and Graen (1984). Lindsey, Homes, and McCall (1991) also reported that educational experiences were the most frequently cited events in one's life that helped contribute to successful leadership development.

2. Religious experiences: Religion is one form of experience that provides individuals with a mechanism for "making sense of life." Wasylyshyn (2001) argued that all human beings are sense-making entities and therefore are looking for ways to figure out life and the direction they should take in the future. There are many examples of leaders who derive their values and objectives on the basis of spiritual and religious foundations (Martin Luther, Gandhi, Martin Luther King, etc.). Bass and Avolio (1993) reported in a biographical study of community leaders that those evaluated by their followers as more transformational had more positively engaging religious experiences while growing up.

3. Parents and siblings and/or other family members: Case studies of leaders have revealed the role of family members in helping them form their values and goals associated with leadership. For example, Standford-Blair and Dickmann (2005) summarized interviews with 36 leaders nominated for their effectiveness and found a number of examples in which individuals identified their parents and other family members as being very influential for their ascendance into leadership roles and their values and styles of leadership. Also, there has been some work linking parental influence to leadership styles seen later in life. Specifically, Avolio and Gibbons (1988) reported that leaders evaluated as more transformational by their followers independently described their parents as being very challenging and supportive, in a balanced way.

Popper and Mayseless (2003) suggested that parents provide the role models for children to identify with in the same way that transformational leaders do with their followers. Such parents help children to develop their self-efficacy for leading others, promote a conviction to a higher set of beliefs and values, and provide the challenges and support for children to build toward success. Avolio (1994) reported that setting high parental moral standards was correlated with components of transformational leadership. Zacharatos, Barling, and Kelloway (2000) reported that athletes in high school who rated their parents as more transformational were in turn rated by their peers as more effective leaders themselves.

4. Experience of loss: Zaleznik (1977) described the twice-born charismatic leader as someone who has experienced a dramatic life

event that changed him or her so dramatically that the individual has become a different person with a radically different life focus. One example often used is the life change in Gandhi after visiting South Africa and seeing the effects of ethnic and racial discrimination. What he observed in terms of the system of Apartheid led him to focus on a higher calling in his work. After being pushed from a train for being "colored," he saw not only the personal injustice but the collective injustice that led to his historic work in India.

McCall, Lombardo, and Morrison (1988) and Lindsey et al. (1991) identified personal traumas as one type of developmental experience affecting leadership development. These included such events as divorces, business failures, learning about personal limits, combat duty, and other experiences sometimes outside the control of the individual. In fact, it is quite common for leaders to describe such losses as turning points in their lives that led them to a deeper understanding of who they were and who they wanted to become. Bennis (2002) suggested that harsh and traumatic experiences revealed a hidden part of one's inner self that, if successfully transcended, can result in greater understanding and compassion for others.

5. Experience of unexpected opportunity: In their study of executive development, McCall et al. (1988) suggested that unexpected opportunities are also important determinants of leadership: "What did seem to characterize the successful executives we studied was not their genetic endowment nor even their impressive array of life experience. Rather, as a group, they seemed ready to grab or create opportunities for growth" (p. 122). This relates in part to the type of climate created in the organization to support taking advantage of unexpected growth opportunities, opportunities for self-reflection, feedback, and debriefing (London & Smither, 1999, 2002).

6. Peer group: According to Day (2000), "Peer relationships offer unique value for development because of the degree of mutual obligation and the duration of the relationship. Organizations should consider peer relationships as a potentially valuable component of an overall leadership development system" (p. 597).

7. Mentor or mentors: The role of a mentor or mentors has surfaced frequently in the interviews of leaders conducted by Standford-Blair and Dickmann (2005). Their interviews revealed that the leaders studied "came into contact with multiple mentors in their formative years. . . . Their mentors served as guides, sources of feedback, role models, skill builders, liaisons, clarifiers, and even constructive criticizers" (p. 20). Bass (1990) and others (e.g., Day, 2000; Kram, 1983) have identified acquiring mentors as an important development experience for individuals moving into leadership roles.

8. Role model who was not a direct acquaintance: Lindsey et al. (1991) reported that role models that had a positive impact on leadership development were not necessarily in direct contact with leaders. Although many individuals report their direct superior as their role model, some report that the role model who had the greatest impact on them was indirect or two or three levels higher in the hierarchy.

9. Training and developmental experiences: Considerable evidence has been accumulated supporting the impact of training and developmental experiences on enhancing leadership development (Burke & Day, 1986; Day, 2001; Reichard & Avolio, 2005). Reichard and Avolio (2005) reported on a comprehensive meta-analysis of the leadership development literature that formal training programs were effective in positively improving leadership. The effects of developmental interventions were consistent across all styles of leadership training, including participative, directive, transactional, and transformational.

10. Prior challenges in jobs: A number of researchers have identified several components of jobs and/or task-related components of jobs that are helpful in leadership development. McCauly, Ruderman, Ohlott, and Morrow (1994) showed that such job demands as creating change, job overload, and facing adverse business conditions represented dimensions of managerial jobs that could impact leadership development. McCall et al. (1988) and Day (2000) likewise identified challenging assignments as having developmental potential for executives. Howard and Bray (1988) in their classic longitudinal study of AT&T managers showed that the breadth and diversity of challenging job assignments in one's career was positively associated with leadership progression. Bettin and Kennedy (1990) have also shown that relevant work experiences (e.g., specific assignments and responsibilities) versus those in general (e.g., time in grade) had the most positive relationship to the leadership of military officers.

11. Prior successes in leadership roles: Avolio (1994) reported on a life history study of community leaders that those rated as more transformational had a broader range of informal and formal leadership experiences and successes during high school and beyond. Yammarino and Bass (1990) found that junior naval officers rated as more transformational by followers were more involved in organized sports and leadership roles. Similar results were provided by Atwater et al. (1994).

We recognize that the above list may not provide a comprehensive coverage of all of the experiences conducive to leadership development. However, these experiences do represent two broad domains of life: family and work. In the studies reviewed above, the events occurring across these two domains, family related and work related, were shown to contribute to one's leadership emergence and development.

Little is known about the relative contribution of these leadership development experiences to individuals' emergence into leadership roles. Even less data and knowledge are available concerning their relative contribution independent of genetic factors. Understanding the family experiences and work-related experiences that may influence leadership ascendance and development could provide insights into optimizing individual leadership development for both men and women. Indeed, unearthing these unique experiences while controlling for genetics may offer some of the most interesting insights into what factors in the life span contribute to leadership emergence that may have been erroneously classified under the "born" versus "made" categorization.

Objectives of the Current Study

The current study expands on the Arvey et al. (2006) study in two ways. The first objective of the current study is to examine the degree to which genetic factors influence leadership role occupancy among a female sample. On the basis of previous research, our hypothesis is that there will be a significant genetic influence and that the degree of genetic influence will be the same as observed in a male sample based on Arvey et al.'s database (30%). A second, and important, objective is to examine a number of

environmental variables that potentially influence leadership and the extent to which they affect leadership role occupancy independent of genetic factors. Although we have some guidance from the literature that these environmental variables will be related to leadership (as noted above), we have no a priori expectations concerning which of them will have greater or less relative influence. Thus, we consider this component of our study exploratory in nature and make no specific hypothesis here.

Method

Sample

The sample for this study was drawn from the Minnesota Twin Registry, which tried to locate surviving twin pairs born in the state from 1936 to 1951 (Lykken, Bouchard, McGue, & Tellegen, 1990). The subsample examined in the present study was restricted to a random sample of 500 pairs out of the 1,317 female twin pairs in the registry. All twins had been reared together during childhood. According to information drawn from an earlier survey of these pairs, 98.6% had lived together for 14 years or longer since birth. In addition to their twin, 18.3% had one other sibling, 18.6% had two other siblings, 21.3% had three other siblings, and 33.8% had four or more other siblings.

We sent surveys to 500 twin pairs (1,000 individuals) and received a total of 596 returned and completed surveys, yielding an individual-level response rate of 60%. Of the returned surveys, 392 included both members of the twin pair, yielding a pair-level response rate of 39%. Of the 196 twin pairs, 107 were identical, or monozygotic, twins and 89 were fraternal, or dizygotic, twins. Ninety-eight percent of the respondents classified themselves as White, and 77% were married. Sixty-seven percent of the sample reported that they worked for a private or public organization, whereas 25% were currently retired. They were geographically dispersed mainly throughout the state of Minnesota, with 23% living in a large city of over 100,000. Other relevant characteristics of the total sample as well as the two twin groups are presented in Table 1. The determination of whether the twin pairs were identical or fraternal had been established previously, as described by Lykken et al. (1990).

Measures

Leadership Role Occupancy

For the present research, we followed the lead provided by Arvey et al. (2006) by measuring 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 others. 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), observing that people in such role positions "lead as a consequence of their status—the power of the position they occupy" (p. 19). In addition, Judge, Bono, Ilies, and Gerhardt (2002) explicitly coded leadership studies that used positional components (e.g., holding a position of leadership in high school as compared with others who did not) as one indicator for leadership emergence.

More recently, Day, Sin, and Chen (2004) used the position of captain of a hockey team as indicative of leadership role occupancy and studied the impact of role occupancy on subsequent 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 (2004) made the point that leadership emergence is the "first step" in the formal 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. 215). In addition, we wish to make explicit that simply because an individual occupied such positional roles, this does not necessarily mean that others will perceive or believe that he or she is indeed a leader or, more specifically, a "good" leader.

Our leadership measure was developed using a biohistory methodology in which respondents indicated past or present participation or role occupation in leadership positions. The biohistory or biographical approach to psychological measurement is a well-known and acceptable procedure for assessing autobiographical or historical events among individuals (Mumford & Stokes, 1992), including assessments of leadership achievement and effectiveness. These types of items have been used previously to assess leadership. For example, Mumford, O'Conner, Clifton, Connelly, and Zaccaro (1993) reported a study in which such items as "How many of the following leadership positions did you hold?" were used to develop a criterion measure of leadership. Similar item types have been reported by Stricker and Rock (1998) to assess leadership potential (i.e., "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 class or school leader, level of seniority in high school extracurricular activities) as measures of past leadership experience. Atwater, Dionne, Avolio, Camobreco, and Lau (1999) also examined the roles and experiences individuals had in leadership positions to predict how those leaders were subsequently rated by followers. In their study, they used life history items that Bass and Avolio (1993) had empirically validated as being associated with transformational leadership. In a study comparing proctored Web-based and paper-and-pencil tests, Ployhart, Weekley, Holtz, and Kemp (2003, p. 741) used this biographical approach to measure leadership by asking questions relating to previous leadership and supervision opportunities.

There is also evidence that biographically 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 and what is found in actual biographical records (with correlations ranging from .90 to .98), indicating that there is little falsification of biographically based measures (Cascio, 1991, p. 265).

Respondents in our study indicated whether they had held or hold positions at work that would be considered managerial in nature. A number of different options were presented (president, manager, supervisor, work group leader, etc.). Table 2 presents the sample responses to these questions. This was the identical measurement scheme used by Arvey et al. (2006).

For each individual, we calculated a score based on these items by assigning 7 points if she checked president (the highest raking

Table 1
Sample Characteristics of the Female Twins

Variable	Identical twin (n = 214)	Fraternal twin (n = 178)	Total (N = 392)
Age (years)			
M	57.1	59.1	58.0
SD	5.8	6.0	6.0
Occupation (%)			
Managerial and administrative	11	8	10
Professional, paraprofessional, and technical	27	21	24
Sales and related	6	6	6
Clerical and administrative support	20	16	18
Service	8	13	10
Agricultural, forestry, fisheries, and related occupations	0	1	1
Production, construction, operations, maintenance, and material handling	3	3	3
Education (%)			
Less than high school	4	4	4
High school	43	49	46
Two-year college/vocational school	24	23	23
BA/BS	21	19	20
MA/MBA	7	5	6
PhD/JD/MD	1	0	1

Note. Sample characteristics are based on individual twins rather than twin pairs. Chi-square analysis showed no significant difference between identical and fraternal twins on all education and occupation items. Results of a t test showed that identical twins were younger than fraternal twins ($t = -3.35$, $p < .05$, $d = -0.34$).

category), 6 points if she checked vice-president (the next highest ranking category) but not president, 5 points if she checked manager but neither of the other two higher ranking categories, and so on. This scoring method has been used previously going back as far as Flemming (1935). The mean leadership role occupancy score for the total sample was 2.64 ($SD = 4.11$), and for the identical and fraternal twin subsamples the means were 2.92 ($SD = 4.57$) and 2.31 ($SD = 3.47$), respectively. Computation of a t test showed no significant difference between identical and fraternal twins ($t = 1.46$, $p > .10$, $d = 0.14$).

It should be noted that in Arvey et al.'s (2006) article, the researchers computed a composite score using the above scoring scheme and combining this score with an additional item assessing the number of work-related professional associations in which the individual had served as a leader. The present study used only the work-related leadership items and not the professional association item; both schemes were examined and yielded virtually identical results, and so we adopted the more parsimonious system of using one score rather than a composite.

If Arvey et al.'s (2006) study had used exactly the same scoring procedure as the current study did, the mean for the male sample on leadership role occupancy would have been 4.13 ($SD = 4.38$, $N = 426$). This score was significantly different from the female sample derived in the present study ($M = 2.64$, $SD = 4.11$, $N = 392$; $t = 5.01$, $p < .005$, $d = 0.35$), which is to be expected given the prior literature pertaining to the underrepresentation of women in positions of leadership.

Reliability of the measure. The reliability of the leadership role occupancy measure was estimated by factor analytic procedure. According to Harman (1967, pp. 16–19), the total variance of a single-item measure can be represented as communality + specificity + error, and "the communality of any variable is less than or equal to the reliability of the variable" (p. 19). Thus, the communality can be considered a conservative estimate of single-item reliability. This method has been used in studies involving single-item physical ability measures (Arvey, Landon, Nutting, & Maxwell, 1992) and single-item measure of teaching effectiveness (Wanous & Hudy, 2001). In the current study, the leadership role occupancy variable was factored along with 22 variables that were not used in the present study. These variables included the following: the 11 personality scales drawn from the Multidimensional Personality Questionnaire (Tellegen, 1982; Tellegen & Waller, 2001), five subscales from the Multifactor Leadership Questionnaire (Avolio & Bass, 1991; Bass & Avolio, 1991), two subscales from the Dispositional Hope Scale developed by Synder et al. (1991), the Core Evaluations Scale (Judge, Erez, Bono, & Thoresen, 2003), and three individual items from the survey instrument we believed should be correlated with the leadership role occupancy measure. The results of this factor analysis showed that (a) the leadership role occupancy variable loaded with variables such as the number of professional associations the respondent held and (b) the measure did not load on factors that are supposed to measure personality traits or years of working.[1] These results provide evidence for the convergent and discriminant validity of the leadership role occupancy measure. Based on the factor analysis, the communality value for this leadership measure was .56.

Construct validity. Evidence is available for the construct validity of this leadership measure by examining its correlations with other individual items and variables. Specifically, the leadership

[1] The factor analysis and construct validity results are available on request from Richard D. Arvey.

Table 2
Responses on Leadership Role Occupancy Item

Measure	Identical twin (n = 214)	Fraternal twin (n = 178)	Total (N = 392)
Hold or have held a position (%)			
Work group leader	29	26	28
Team leader	25	22	24
Shift supervisor	14	16	15
Manager	22	16	19
Director	7	7	7
Vice-president	3	1	2
President	5	1	3
Leadership role occupancy (raw score)			
M	2.92	2.31	2.64
SD	4.57	3.47	4.11
Leadership role occupancy (natural log transformed)			
M	.89	.78	.84
SD	.94	.88	.91

Note. Chi-square analysis showed no significant difference in percentage between identical and fraternal twins on the position items. Results of a t test showed no difference on the leadership role occupancy variable (t = 1.46, $p > .10$, d = 0.14). The comparisons are based on individual twins rather than twin pairs.

role occupancy variable correlated significantly with the number of professional associations led by the respondent (r = .21, $p <$ .001, N = 388 owing to missing data) and with scales formed using similar biohistory items in which respondents reported their past leadership activities in high school (r = .31, $p < .001$) and in current community activities (r = .15, $p < .01$). This variable was also correlated with whether they held managerial and administrative occupations (r = .20, $p < .01$) and transformational leadership behaviors (r = .31, $p < .01$). In addition, the measure was uncorrelated with a number of variables for which there were no a priori expectations of a relationship (i.e., marital status, r = –.03, $p > .70$; number of siblings, r = –.07, $p > .50$; contact frequency with twin, r = –.03, $p > .70$).

Developmental Experiences

Respondents were asked to review their history of holding positions of leadership and to indicate whether there were any particular "critical" or "trigger" events or people that motivated them to move into those roles. They were given 13 different experiences and asked to check whether each was applicable (0 = no response, 1 = yes). These experiences are shown in Table 3 along with their endorsement rates. These items were developed using the literature cited above.

Construct validity. The various items were correlated with other variables with which they were expected to demonstrate significant relationships. In particular, we expected respondents' endorsement of educational experiences as a critical factor to correlate positively with their educational achievement. This correlation was indeed highly significant (r = .46, $p < .01$). We expected that individuals who reported their past religious experiences as a critical factor would also report participation and the exhibition of leadership in religious activities in high school, college, and their community. These correlations were all significant; for example, the correlation between subjects' reporting of religious experiences as critical events motivating them into leadership roles at work and their involvement as a leader in religious activities in their communities was .44 ($p < .01$). We also expected that individuals' indication of prior challenges in past jobs and prior successes in leadership roles would correlate with a number of work-oriented activities that represented leadership. The correlations of prior challenges in past jobs with "take charge of a project" (r = .37, $p < .01$) and "coordinated a special event" (r = .35, $p < .01$) were as expected, as were the correlations of prior successes in leadership with "present project results" (r = .41, $p < .01$) and "take charge of a project" (r = .36, $p < .01$). Other information indicated that these critical experiences correlated negatively or not at all with other variables as expected. For example, living on a farm correlated –.18 ($p < .01$) with prior challenges in past jobs and –.12 ($p < .01$) with prior success in leadership. Participation in a dance group showed no significant correlations with the various critical events, as would be expected.

Additional validation evidence was gathered by correlating subjects' coded written narrative statements in which they described two critical events or people that motivated them to assume a leadership role or roles with the 13 specific item categories. Statements were written by 229 of the 392 subjects (matched twins), and in many cases the statements were extensive. Two of the authors, who were blind to specific subject endorsement to the item categories, then independently content analyzed these statements using the various item categories described above. Each narrative was scored simply as 1 if it seemed to reflect a specific item category. The average initial agreement between the two authors across the different categories was 81%. After discrepancies were reviewed, consensus was achieved in terms of which category the narratives best fit, and narratives were scored accordingly. Subsequently, correlations were computed between the 0–1 dichotomy of each item and the 0–1 dichotomy based on the content analysis of the narrative categories across the subjects. The average across the correlations was .30 (ranging from .02 to .51), and all were statistically significant with the exception of the

Table 3
Factor Loadings of Developmental Items

Critical event or person	Endorsement rates (%) (N = 392)	Work experience	Family experience
My religious experiences	29	.09	**.59**
My parents	26	−.01	**.97**
My siblings	18	−.04	**.64**
Someone in my family other than parents or siblings[a]	9		
My educational experiences	31	**.64**	.18
Experiencing unexpected opportunity	17	**.49**	.06
Experiencing some loss[a]	10		
Someone in my peer group	24	**.52**	−.09
A mentor or mentors	17	**.65**	−.10
A role model who was not a direct acquaintance	10	**.40**	.08
Training and developmental experiences	33	**.82**	−.08
Prior challenges in past jobs that prepared me	29	**.73**	−.05
Prior successes in leadership roles	16	**.67**	.16
Eigenvalue		3.15	2.80
Variance explained		28.6%	25.5%
Reliability (Kuder-Richardson Formula 20)		.68	.62

Note. Participants responded to the question "Were there any particular 'critical' events or people that motivated you to move into leadership role? (Check all that apply)." Exploratory factor analysis was based on a tetrachoric correlation matrix generated by LISREL. Factor loadings ≥ .40 appear in boldface type.
[a] These two items were excluded from factor analysis owing to low communality value.

category "prior successes in leadership roles" (r = .02, $p > .70$). Overall, these correlations indicate consistency between what subjects mentioned in their narratives about their developmental experiences and their written responses to the specific items. Also, the correlations are not exceptionally high such that one might suspect that the subjects were simply trying to maintain consistency across the two different response formats.

Factor analysis of the items. A factor analysis of these items was conducted using principle-axis factoring and oblique rotation based on the tetrachoric correlation matrix. These results are also shown in Table 3, and they confirm two broad factors. The first factor accounted for 28.6% of the variance and reflected external experiences in work and educational contexts; the highest loadings were on the items "Training and developmental experiences" (.82), "Prior challenges in past jobs that prepared me" (.73), "Prior success in leadership roles" (.67); and "My educational experiences" (.64). In addition, items involving role models, mentors, and peers also showed high loadings on this factor. Although it is not clear from these items that the individuals referred to were encountered within work or educational contexts, the narratives we read indicated that they did refer to individuals in these two settings. Thus, it is likely that most, but not all, of these experiences were based on occurrences in work or educational contexts. On the basis of these data, we labeled this factor *Work Experience*, recognizing that educational experiences also contributed to this factor. The second factor (labeled *Family Experience*) accounted for 25.5% of the variance and clearly reflects a family factor, with the highest loading found on the "my parents" option (.97). "My religious experiences" also loaded on this factor (.59); the narratives revealed that subjects were referring to this religious experience predominantly in the context of their early home life and upbringing. Scores on the two factors were derived for each individual. The internal consistency reliability estimates of the Work and Family Experience factors were .68 and .62, respectively, using the Kuder–Richardson Formula 20.

Analytical Approach

As the first step in our primary analysis, we correlated the leadership role occupancy variable on the individual developmental items as well as the two developmental factors (i.e., derived factor scores) in order to conduct a preliminarily test of these developmental influences on leadership role occupancy. In the second step, we examined the heritability of leadership role occupancy together with the two developmental factors using a multivariate two-group confirmatory structural equation modeling (SEM) analysis. This is the standard behavioral genetics method of examining the degree of similarity of individual twins and analyzing covariance among particular measures of interest (Plomin, DeFries, McClearn, & McGuffin, 2001). The method of maximum likelihood as operationalized in the software program LISREL (Jöreskog & Sörbom, 1999) was used. The underlying logic of this analysis is to decompose and estimate the variance of any observed measure and the covariance between two measures into three parts that result from, respectively, genetic effects (A), common environmental effects (C), and nonshared environmental effects and error (E). The C factor refers to influences shared by members of the same family (income level, number of books in the home, high school, etc.—those features of the environment shared by each twin). The E factor includes unique environmental influences as well as measurement error. A detailed explanation of the underlying assumptions and estimation methods for the univariate analysis is provided in the Appendix. The multivariate analysis is a direct extension to multiple variables.

Following the practice of behavioral genetic research using this model, we examined differences in model specification, testing a

full model (with A, C, and E factors all present) against alternative nested models—a reduced model with only A and E factors, a model with only C and E factors, or a model with only the E factor—to determine the significance of the corresponding path coefficients. If, for example, all of the path coefficient *c*s are nonsignificant, the reduced A and E factor model will show little chi-square change and will probably have better fit indexes than the full A, C, and E factor model.

Figure 1 shows a schematic path diagram of the full model. For illustrative purposes, only latent genetic factors (A) are displayed for one twin; the C and E latent factors are ignored for simplicity. A_F, A_W, and A_L refer to the latent genetic factors for family experience, work experience, and leadership role occupancy, respectively. The full model has two groups, and each group has six observed variables for two twins (see the Appendix for the input matrices for SEM analysis). This model can partial out the variance of the leadership variable that is shared with other variables versus variance that is unique to this leadership variable. In particular, genetic effects on the leadership measure were decomposed into two components. First, the path coefficients a_{13} and a_{23} represent genetic effects on the leadership variable that overlap with genetic effects on the two developmental factors. Second, the a_{33} coefficient represents the unique genetic effects on leadership. Similarly, each of the two developmental factors can be decomposed into parts that represent common and unique environmental influences. For clarity purposes, we do not show the 12 pathways for the C and E factors in Figure 1.

Results from this analysis also reveal whether the two developmental factors have any genetic influence. Although this may seem counterintuitive, there is substantial previous research showing greater similarity among identical twins compared with fraternal twins with regard to their *perceived* environmental features, suggesting a genetic influence. Indeed, Hershberger, Lichtenstein, and Knox (1994) showed a genetic influence for organizational climate dimensions previously thought to be essentially environmentally established. Plomin (1994) provided various explanations as to why such relationships may exist. More discussion about this issue is provided later.

This step can simultaneously answer our two research questions—that is, whether genetic factors significantly influence leadership role occupancy and the extent to which the developmental factors affect leadership role occupancy, independent of genetic effects for women.

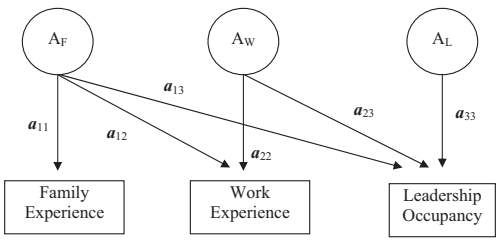

Figure 1. Multivariate model showing only one twin in a pair. For purposes of clarity, only the A (genetic effects) factors are shown, whereas the full model also has C (common environmental) and E (nonshared environmental and error) factors for both twins in a pair. A_F, A_W, and A_L refer to the latent genetic factors for family experience, work experience, and leadership role occupancy, respectively.

Results

Correlations

Table 4 provides the zero-order correlations between the various developmental experience items and two derived developmental experience factors with the leadership construct. The leadership role occupancy variable was significantly correlated with 10 of the 13 developmental experiences at the $p < .01$ level. The highest correlation observed was with the "training and developmental experiences" item ($r = .35$, $p < .01$). The two developmental factors were likewise correlated significantly with the leadership variable (Family Experience, $r = .22$, $p < .01$; Work Experience, $r = .40$, $p < .01$). Thus, it appears from these results that a variety of developmental experiences are associated with the movement of individuals into leadership roles, with the experiences in actual work contexts perhaps being given more relative importance by subjects, on the basis of the initial size of the zero-order correlations.

For the purposes of two-group SEM analyses, the leadership role occupancy variable was transformed (after adding 1) by using a natural log transformation to provide more equal variances in this variable between the two groups of twins. The value of 1 was added to the variables before the natural log transformation to avoid the ln(0) situation. Table 4 provides the correlations of other variables with this log-transformed leadership variable, which are very similar to those between the original leadership variable and the developmental items.

Overall Genetic Influence on Leadership

Our purpose was to examine whether there is a significant genetic influence on leadership role occupancy among women. Table 5 presents the results of model-fitting processes to answer this question. A series of two-group structural equation models were tested against each other. Six criterion indexes were chosen to evaluate the model fits: the traditional chi-square test, Akaike's information criterion (Akaike, 1983, Steiger's (1990) root-mean-square error of approximation (RMSEA), the incremental fit index, Bentler's (1990) comparative fit index, and the goodness-of-fit index. In addition, the 90% confidence intervals of RMSEA and the power for test of model fit based on RMSEA are reported when available.

In the full ACE model (Table 5, Model 1), all three variables (the leadership variable and the two developmental experience factors) are decomposed into their respective A, C, and E parts. The AE model (Model 2) did not exhibit significantly worse fit than the full ACE model (Model 1), which means that all of the paths representing common environmental influences (C factors) are nonsignificant (i.e., as determined by an omnibus test). In Model 2, the two paths from the E factor of Family Experience to the other variables were not significant at the .05 level. After these two paths were fixed to zero (see Figure 2 for the fixed paths), the further reduced model (Model 3) fit particularly well in terms of the five fit indexes. The point estimate of RMSEA was .02, and both the comparative fit index and the incremental fit index were .99. Though not shown in Table 5, those models that failed to incorporate genetic factors produced very poor fits. Thus, Model 3 is the final model, and Figure 2 shows the estimates of the

Table 4
Means, Standard Deviations, and Zero-Order Correlations of Developmental Influences and Leadership Measure

Variable	*M*	*SD*	1	2	3	4
1. Leadership role occupancy	2.64	4.11	—	.88	.22	.40
2. Log (leadership)	0.84	0.91	.88	—	.19	.48
3. Family Experience factor	2.04	0.42	.22	.19	—	.13
Religious experiences	0.29	0.45	.10	.08	.54	.18
Parents	0.26	0.44	.22	.19	.98	.11
Siblings	0.18	0.38	.18	.14	.49	.06
Other family member[a]	0.12	0.33	.01	.04	.09	.08
4. Work Experience factor	2.39	0.36	.40	.48	.13	—
Educational experiences	0.31	0.46	.21	.25	.37	.62
Unexpected opportunity	0.17	0.37	.24	.28	.17	.37
Experiencing some loss[a]	0.13	0.33	.07	.08	.16	.13
Peer group	0.24	0.43	.14	.14	.07	.37
A mentor or mentors	0.17	0.38	.22	.27	.08	.46
A role model	0.10	0.30	.21	.19	.15	.25
Training and developmental	0.33	0.47	.35	.39	.18	.79
Prior challenges in past jobs	0.29	0.46	.22	.33	.14	.65
Prior successes in leadership	0.16	0.37	.33	.33	.30	.56

Note. $N = 392$ for all variables. Correlations greater than .10 are significant at $p < .05$; correlations greater than .13 are significant at $p < .01$. Full correlation matrix is available on request from Richard D. Arvey. Correlations among variables are at the individual twin level. This matrix is not the input matrix for the multigroup confirmatory structural equation modeling analysis; the actually input matrices are the variance-covariance matrices of Twin 1 and Twin 2 variables for each of the two groups.
[a] These two items were excluded from factor analysis owing to low communality value.

standardized path coefficients for this model. The confidence intervals of these path coefficients are reported in Table 6. These results indicate that the shared environment of twins (C factors) had little influence on the three variables.

According to Model 3, the percentage of the variance of leadership role occupancy that can be attributed to genetic factors (i.e., the heritability estimate, h^2) is 32% (95% confidence intervals of .16 and .48). This point estimate is calculated by dividing the sum of the squared path coefficients related to all of the three A factors by the sum of the squared path coefficients from both of the various A and E factors. This result confirms our hypothesis in that there are significant genetic influences on the leadership role occupancy reported by females. It should be noted that this interval also includes the heritability estimate found for the male sample in the Arvey et al. (2006) study. The point estimate for the male sample and that found here are very close to each other (the estimate for the male sample was. 30 before log transformation and .28 after transformation). Although not shown here, a test of the differences between the heritabilities of the male sample (using data from Arvey et al.'s study) and the female sample was not significant.

Model 3 also provides estimates of the genetic influence on the two developmental factors. Although these two factors are believed to be "environmentally induced" experiences, analysis showed that they both are genetically influenced. In total, 33% and 31% of the respective variance of the Family Experience and Work Experience factors can be explained by genetic influences. These results are consistent with previous findings that show genetic effects on perceptual measures of environmental variables. More discussion on this issue is provided shortly.

Table 5
Model Fitting on Leadership and Two Developmental Factors

	Fit index							
Model	$\chi^2(df)$	$\Delta\chi^2$	Δdf	RMSEA (90% CI)	AIC	IFI	CFI	GFI[a]
Model 1: Full ACE model	11.8 (6)			.11 (.01, .20)	49.2	.96	.95	.97
Model 2: AE model	13.3 (12)	1.5	6	.04 (.00, .12)	38.4	.98	.98	.98
Model 3: Reduced AE model	14.5 (14)	1.2	2	.02 (.00, .10)	35.6	.99	.99	.98

Note. Sample size was 107/89 (identical/fraternal) pairs. Model 2 is the reduced model with all C paths in Model 1 fixed to 0. Model 3 further fixed the two nonsignificant paths in Model 2 to zero. RMSEA = root-mean-square error of approximation; CI = confidence interval; AIC = Akaike's information criterion; IFI = incremental fit index; CFI = comparative fit index; GFI = goodness-of-fit index.
[a] Mean GFI of the two groups is reported.

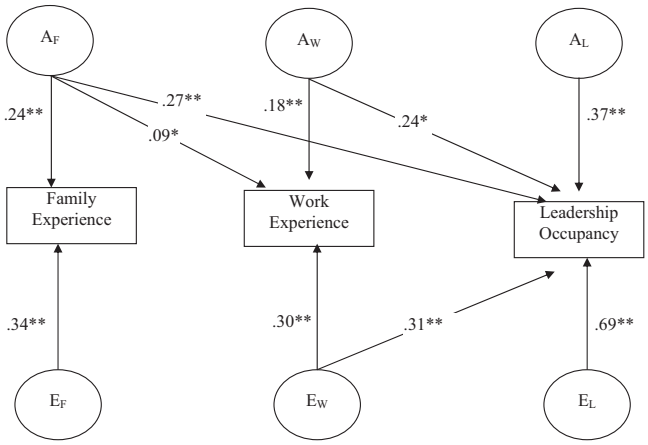

Figure 2. Final model (Model 3 in Table 5) with standardized path coefficients. A_F, A_W, and A_L refer to the latent genetic factors for family experience, work experience, and leadership role occupancy, respectively. E_F, E_W, and E_L refer to the nonshared (or unique) environmental factors for family experience, work experience, and leadership role occupancy, respectively.

Genetic Influences on the Developmental Factors

Figure 2 and Table 6 show that the A and E components of the Family and Work Experience factors also contributed to the leadership variable. The observed associations between the two developmental factors and leadership can be decomposed into genetic associations and nongenetic ones. In particular, the genetic materials that influence Family Experience and Work Experience also significantly impact leadership role occupancy (βs = .27 and .24, respectively). The two developmental factors account for a significant portion of the total genetic influences on the leadership variable: $(.27^2 + .24^2) / (.27^2 + .24^2 + .37^2) = 49\%$. In addition, they account for 16% (49% * 32%) of the total variance of the leadership variable. Figure 3 illustrates the decomposition of the variance of leadership role occupancy into genetic and nongenetic parts.

In addition, Figure 2 reveals that the standardized path coefficients from A_L and E_L factors to the leadership variable are .37 and .69, respectively. They represent the unique genetic and environmental influences, after controlling for the two developmental factors.

Nongenetic Influences on Leadership

The second objective of the current study was to examine the extent to which "pure" developmental factors affect leadership role occupancy, independent of genetic factors. Figure 2 shows that the environmental component (E) of the Work Experience factor significantly affected leadership role occupancy (β = .31), whereas the environmental component of the Family Experience factor was nonsignificant.

Work Experience accounted for 17% of the variance in the leadership variable explained by nongenetic factors, that is, $(.31^2) / (.31^2 + .69^2) = 17\%$, which is 12% (or 17% * $[1 - h^2]$, where $h^2 = .32$) of the total variance. In contrast, the Family Experience factor had only genetic influence on the leadership variable. In other words, the observed association between the Family Experience factor and leadership role occupancy was due solely to their overlap on latent genetic components, and there was no overlap on their nonshared environmental components, as indicated by the absence of a path linking E_F to the leadership variable. Thus, after the confounded impacts of genetic influences of the two developmental factors are partialed out, the pure developmental effect comes only from Work Experience and contributes to 12% of the total variance of the leadership variable. See Table 6 for a summary of the decomposition of the total variance.

In summary, the proportion of variance due to the genetic factors for the leadership variable was estimated at .32. With regard to our research question, the developmental effect of the Work Experience factor explains a substantial amount (12%) of the total variance of the leadership role occupancy, independent of the genetic effects. In contrast, the Family Experience factor was not significantly related to the leadership variable after the genetic effects were partialed out.

Table 6
Estimates of the Standardized Path Coefficients in the Final Model

	Genetic factors			Nonshared environmental factors		
Variable	A_{Fam}	A_{Work}	A_{Lead}	E_{Fam}	E_{Work}	E_{Lead}
Family Experience factor	.24** (.17, .30)			.34** (.30, .39)		
Work Experience factor	.09* (.03, .15)	.18** (.10, .24)			.30** (.26, .33)	
Leadership role occupancy	.27** (.12, .43)	.24* (.02, .43)	.37** (.19, .50)		.31** (.19, .43)	.69** (.61, .77)
Leadership variance explained (%)	8.7%	6.9%	16.3%		11.5%	56.6%

Note. The 95% confidence intervals are reported in parentheses. Fam = Family Experience factor; Work = Work Experience factor; Lead = leadership variable.
* $p < .05$. ** $p < .01$.

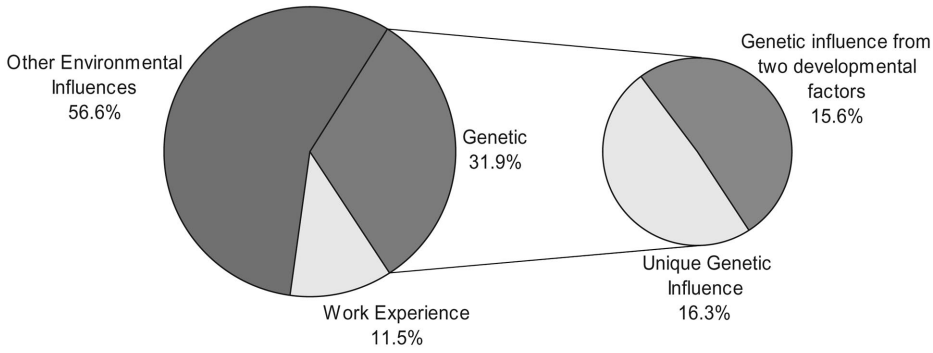

Figure 3. Genetic versus environmental influences on leadership role occupancy.

Discussion

This study found significant genetic influence on the leadership role occupancy of women. Family Experience and Work Experience factors correlated with the leadership variable as well. Of particular note is that the Work Experience factor showed a substantially higher correlation with the leadership role occupancy variable (.48) compared with the correlation shown with the Family Experience factor (.18), suggesting that experiences at work are perhaps more important in shaping developmental components of women's careers and their entry into leadership roles. These data affirm prior research regarding the impact of such experiences in preparing individuals for future leadership roles and represents relatively good news for organizations wishing to move women into formal leadership roles. There are a number of developmental experiences that can help women move into these roles, and we found that the nature of "nurture" makes a difference.

Multivariate analyses helped to tease apart the relative contributions of these developmental factors in the explanation of the variance of leadership role occupancy. We found that almost half of the heritable variance in the leadership variable overlapped with the heritable variance in the two developmental factors. The developmental factor Work Experience also explained 17% of the environmental influences on the leadership variable, whereas other environmental forces (not identified in the current article) accounted for the major part of the nonshared environmental variance. In other words, much remains to be discovered in terms of the environmental influences that uniquely contribute to leadership role occupancy beyond those developmental experiences and events surveyed in the current study. At the same time, we also need to explore how being in leadership roles interacts with genetics in terms of shaping individuality and development over the life span.

Although it seems counterintuitive that the shared or common environment factor failed to show a significant relationship with the leadership variable, this does not necessarily mean that there are no family determinants. Another interpretation is simply that each twin experiences her family in individualistic ways—what might be important and critical to one twin might not be important to the other, even if both experience the same event. And, of course, twins will have different experiences even within their family environments and will vary in terms of how those experiences are interpreted. That is, each twin has a special and unique relationship with her family members (including her twin), and this is captured in the nonshared environmental factor.

The current study also found that there were genetic factors associated with developmental experiences. How can an environmental variable be heritable? In fact, the measure of an environmental variable can show heritability because other characteristics associated with this environmental variable are heritable. The association between the environmental variables and other heritable variables, such as leadership role occupancy in the current study, can possibly be explained by three non-mutually-exclusive mechanisms. First, individuals can passively be exposed to family environments that are correlated with their genetic propensities. For example, leadership-talented children are likely to have leadership-gifted parents who provide them with both genes and an environment conducive to the development of leadership. Thus, the individuals who possess leadership potential may have parents in leadership roles as well as a family environment more conducive to developing their leadership acumen. This study found that a substantial part of the correlation between Family Experience and leadership role occupancy was due to genetic correlations, which partially support this mechanism.

Second, individuals' leadership characteristics can also evoke responses from others that shape the environment. That is, leadership-talented individuals might be identified in school and at work very early on and given special opportunities to learn about assuming leadership roles in lower risk environments than those available later in life (Avolio, 1999).

Third, individuals can, in addition, actively select or create their own environments that are consistent with their genetic propensities. For example, even if others do not influence a child's leadership potential, the individual might select or even create an environment that helps to develop his or her leadership talents through a process often called niche picking or niche building (Plomin, 1994). The fact that a significant part of the correlation between leadership and Work Experience is due to shared genetic influences can support the second and third mechanisms. Unfortunately, we cannot disentangle the three mechanisms with the data in the current study.

Limitations and Extensions

There are a number of important limitations of the present research. The first is the issue of response bias being responsible

for the various associations because of the self-report nature of our survey instrument and the possibility that subjects respond similarly to all items. However, if there is a genetic disposition for identical twins to answer these self-report measures more similarly than fraternal twins regardless of the content, all the questions associated with leadership, developmental items, and so forth would appear to be genetically influenced. However, in other analyses conducted with other sections of the survey, we found little evidence for such genetic effects. Thus, response bias seems to be of less concern in the current study, although it is certainly not ruled out.

Another issue involves the particular sample we used: female twins born in Minnesota. Unless one believes that individuals born in Minnesota are dramatically different from female twins or other random samples of females elsewhere, this argument may not appreciably alter our interpretation of the current findings. However, it should be noted that other demographic factors, such as the fact that the sample was 98% White and U.S. based, must be considered in future behavioral genetics research on leadership that examines the generalizability of our findings. We do note that it appears as if genetic factors account for a similar portion of the variance in our leadership variables as compared with a male sample from the same population base. What is not explored here is whether the same genetic factors are operative for both males and females. It could be that particular constellations of traits and abilities between males and females are differentially impacted genetically and that these different traits and abilities are also differentially related to leadership. As one example of research exploring this issue in another domain, Finkel and McGue (1997) showed significant sex differences in the heritability of several personality traits.

An additional limitation is the particular measure of leadership we used. We presented evidence for the validity of this measure, but one question concerns whether it is indeed a measure of "leadership" as the concept is commonly understood. As we argued earlier, our measure assessed whether one was in a leadership role rather than one's effectiveness as a leader. One typically (but not always) enjoys some positional power and authority associated with occupying a leadership role before one can "behave" in that role. Thus, we have not addressed the question of leadership effectiveness; rather, we have examined the factors that contribute to why some people end up in leadership roles and others do not. On a practical level, gender disparities exist in the occupation of leadership roles, an issue that has garnered a lot of heat, and sometimes light, in debates. Discovering what contributes to this disparity would seem to be a worthwhile endeavor.

We also note the limitations regarding the relatively broad nature of the developmental experiences we identified and measured in the present study. It is possible that some of the covariance among the developmental items could reflect individuals' attributional biases or their tendency to endorse items similarly. One notion is that individuals with particular personality traits might respond similarly to these items. To examine this possibility, we used personality data on the twins in our study and conducted several analyses to determine the relationships between Multidimensional Personality Questionnaire (Tellegen, 1982) variables and the developmental experience items. Our analyses found several significant but weak relationships between the various personality variables and responses on the developmental items. We also used regression methods to predict the leadership variable using the two developmental factors, partialing out the personality variables, and found that the developmental factors were still significant, indicating that personality constructs were not solely responsible for the relationships observed. Future research could explore these developmental experiences in far greater specificity using interview and other qualitative research methods to triangulate around what is obtained from survey measures.

Conclusions and Implications

There is evidence that if individuals believe leadership is a trait and/or born, then they are less likely to engage in leadership development and be successful (Maurer, 2002). Yet the accumulated research clearly suggests that genetics accounts for only some 30% of the variance in leadership ratings and leadership role occupancy. Another 10–15% of the variance appears to be attributable to work and broader life events, whereas the remaining 50% is as yet undiscovered. This is a message that needs to be communicated to leadership practitioners as well as to individuals who have the potential to lead but may believe it is not possible for them to learn how. The evidence for both males and females clearly indicates that this assumption is not warranted.

What these results suggest is that more precise efforts to develop particular aspects of leadership may account for variance in explaining who emerges in leadership roles and who does not. We suspect that a more precise and focused intervention to develop such things as leadership efficacy and leadership style will add to the existing life events and genetic factors that predict leadership emergence and effectiveness. A clear outcome for leadership developers based on these findings is that the amount of unexplained variance in leadership role occupancy and emergence is sufficient to warrant further investment in well-validated leadership development interventions. This leaves open even greater potential for groups, such as women, that have been underrepresented in such leadership roles, and that in and of itself is a critical message to get into the debate about how people end up as leaders.

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Appendix

Underlying Assumptions and Estimation Methods for the Univariate Analysis

Figure A1 presents a simple (univariate) two-group structural equation model. It describes the relationships between the two variables (i.e., variable *X* measured for two twins) in either the identical twins group (where the correlation between the A factors is 1.0) or the fraternal twins group (where the correlation is .50). The correlations between the latent factors (A, C, and E) are set according to behavioral genetics theory; that is, identical twins share all of their genetic material, whereas fraternal twins share, on average, one half of their genes. The correlation for common environmental factors between pair members of both twin types is set at 1.0, reflecting the assumption of equal common environmental influences, whereas the path between the nonshared environmental factors for the twins is, by definition, specified as zero.

Path coefficients *a*, *c*, and *e* are held invariant between the two groups. 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 its relative influence:

$$\mathrm{var}_{(\mathrm{leadership})} = a^2 + c^2 + e^2.$$

The heritability (h^2) is defined as the proportion of total variance that is associated with genetic factors:

$$h^2 = a^2/\mathrm{var}_{(\mathrm{leadership})}.$$

In univariate analysis as shown in Figure A1, the input matrices for structural equation modeling are 2×2 variance–covariance matrices for each group. For multivariate analyses, the input matrices are $2k \times 2k$ variance–covariance matrices for each group, where k is the number of variables measured for both Twin 1 and Twin 2 in a pair. For example, for each group the input matrix for the full ACE model shown in Figure 1 is as follows:

$$\begin{pmatrix} Var(X_1) & & & & & \\ Cov(X_1Y_1) & Var(Y_1) & & & & \\ Cov(X_1Z_1) & Cov(Y_1Z_1) & Var(Z_1) & & & \\ Cov(X_1X_2) & Cov(Y_1X_2) & Cov(Z_1X_2) & Var(X_2) & & \\ Cov(X_1Y_2) & Cov(Y_1Y_2) & Cov(Z_1Y_2) & Cov(X_2Y_2) & Var(Y_2) & \\ Cov(X_1Z_2) & Cov(Y_1Z_2) & Cov(Z_1Z_2) & Cov(X_2Z_2) & Cov(Y_2Z_2) & Var(Z_2) \end{pmatrix},$$

where *X*, *Y*, and *Z* refer to three variables, and subscripts 1 and 2 refer to the first twin and second twin in a given pair.

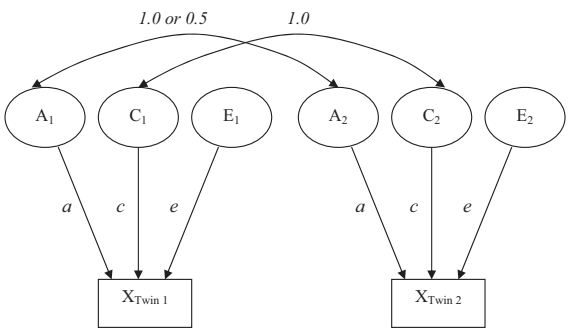

Figure A1. Path diagram of univariate analysis.

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