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The genetic basis of entrepreneurship: Effects of gender and personality

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ABSTRACT

Extending previous research on the genetic underpinnings of entrepreneurship, we investigate gender differences in the genetic influences on the tendency of people to become entrepreneurs. We also examined two mediating variables through which genetic factors may impact this tendency: extraversion and neuroticism. Based on 1285 pairs of identical twins (449 male and 836 female pairs) and 849 pairs of same-sex fraternal twins (283 male and 566 female pairs), we found that females have a strong genetic influence and zero shared-environmental influences on their tendency to become entrepreneurs. In contrast, males show zero genetic influence, but a large shared-environmental influence. Extraversion and neuroticism mediate the genetic influences on women's tendency to become entrepreneurs, whereas extraversion mediates shared-environmental influences on men's tendency to become entrepreneurs. We discuss this sharp difference in genetic influences on entrepreneurship across gender groups and highlight the different challenges that men and women face in their entrepreneurial endeavors.

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Researchers have started to use behavioral genetics methods to investigate phenomena in the world of business in the last several decades (Ilies, Arvey, & Bouchard, 2006). For example, various constructs related to organizational behavior have been shown to have a genetic component including job attitudes (e.g., Arvey, Bouchard, Segal, & Abraham, 1989; Arvey, McCall, Bouchard, Taubman, & Cavanaugh, 1994), vocational interests (e.g., Lykken, Bouchard, McGue, & Tellegen, 1993), work values (e.g., Keller, Bouchard, Arvey, Segal, & Dawes, 1992), and leadership (e.g., Arvey, Zhang, Avolio, & Krueger, 2007). Recently, Nicolaou and colleagues (Nicolaou & Shane, 2009; Nicolaou, Shane, Cherkas, Hunkin, & Spector, 2008; Nicolaou, Shane, Cherkas, & Spector, 2008) have conceptually argued, and have provided empirical evidence for a genetic underpinning of entrepreneurship.

Based on a large sample of identical and fraternal twins from the United Kingdom, Nicolaou, Shane, Cherkas, Hunkin et al. (2008) found a high degree of heritability associated with entrepreneurial behaviors. Heritability is the proportion of variance in a variable attributable to genetic factors (Loehlin, 1992). Nicolaou and his colleagues reported that around 37–42% of the variance in entrepreneurship could be accounted for by genetic factors, whereas non-shared-environmental factors (i.e., the unique environment that people experience, despite growing up in the same family) accounted for the remaining variance. Shared-environmental effects (i.e., the extent to which growing up in the same family makes people similar) failed to significantly influence individuals' tendency to become entrepreneurs. Based on the same sample, Nicolaou, Shane, Cherkas, and Spector (2008) found that sensation-seeking served as a partial mediator of the genetic influence on entrepreneurship. Results such as these provide support for the critical role played by biology and individual differences in explaining the entrepreneurship process (Shane, 2003; White, Thornhill, & Hampson, 2006, 2007).

Several important questions emerge in Nicolaou, Shane, Cherkas, Hunkin et al.'s (2008), Nicolaou, Shane, Cherkas, & Spector's (2008) studies that merit further investigation. First, Nicolaou and colleagues used a twin sample that consisted of predominantly females (i.e., about 93% of the twins were female). Thus the results of their research may be limited in terms of the generalizability of their findings to male samples. Researchers have long argued that women and men face different environments in various stages of the entrepreneurship processes (e.g., Brush, 1992; Jennings & McDougald, 2007; Langowitz & Minniti, 2007). If the environment

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provides different levels of resources, opportunities, and support for women versus men, it is then possible that there may be gender differences in the environmental effects on entrepreneurship for males versus females.

Since the behavioral genetics model differentiates genetic and environmental effects when accounting for the variance of observed variables (Loehlin, 1992), estimating separate models for women versus men could uncover any differences in environment and heritability estimates of entrepreneurship across gender. Such differences would not be without precedent. Past research has shown large gender differences in the genetic influences on life events, social relationships, and delinquent behaviors (e.g., Eley, Lichtenstein, & Stevenson, 1999; Lichtenstein & Pedersen, 1995; Saudino, Pedersen, Lichtenstein, McClearn, & Plomin, 1997). As such, the need exists to examine potential gender differences in the genetic underpinnings of entrepreneurship.

A second and, we believe more interesting question concerns the role that personality characteristics play in the relationship between genetics and the tendency of individuals to become entrepreneurs. Various personality variables that have been found to predict entrepreneurship also have genetic underpinnings. For example, extraversion represents the tendency to be outgoing, assertive, active, and excitement-seeking. Extraversion has been shown to be positively associated with whether an individual becomes an entrepreneur (e.g., Babb & Babb, 1992; Roberts, 1991). Moreover, there is strong evidence supporting the genetic underpinnings of extraversion (e.g., Eaves, Eysenck, & Martin, 1989; Loehlin, 1992; Loehlin, McCrae, Costa, & John, 1998). Thus, as suggested by Nicolaou and Shane (2009), we believe it is important to investigate whether any genetic effects on entrepreneurship function through (or are mediated by) an individual's level of extraversion.

Nicolaou, Shane, Cherkas and Spector (2008) have provided some initial support for examining whether extraversion might operate as a mediator by reporting that women's sensation-seeking (a facet of extraversion) partially mediated the effect of genetics on their entrepreneurship. The identification of such personality mediators is useful because it helps to explain the underlying mechanisms through which genetics and environmental factors impact entrepreneurship by identifying the various sources of variation that contribute to the propensity of people to become entrepreneurs.

The current study attempts to address these two questions using a large sample of female and male twins drawn from the Swedish Twin Registry (see Pedersen, Lichtenstein, & Svedberg, 2002). Drawing upon the literature on gender differences in entrepreneurship, the gene-environment interactions literature, and discussions of gender differences in behavioral genetics literature, we propose and test three hypotheses that focus on explicating how gender, personality, and genetic factors relate to the emergence of entrepreneurs. More specifically, in the current paper we examine the mediating role played by two personality variables (extraversion and neuroticism) with respect to the genetic effects on entrepreneurship comparing male and female twins.

This study expands on previous work in this domain (e.g., Nicolaou, Shane, Cherkas, Hunkin, et al., 2008; Nicolaou, Shane, Cherkas, & Spector, 2008) and contributes to the entrepreneurship literature in three ways. First, we investigate how gender relates to the influences of personality and genetic factors on the emergence of entrepreneurs. Second, we explore how shared-environmental factors, or the lack thereof, as compared with genetic factors, contribute to the propensity of people to become entrepreneurs. Prior literature has not differentiated genetic transmission from family-related factors in explaining how entrepreneurs emerge. For example, researchers have studied the effects of parents' role modeling and transferring of social and financial capital on children's entrepreneurship propensity (see Sorenson, 2007). However, without explicitly modeling the genetic endowments transmitted from parents, these family-related variables may not represent pure *environmental* influences. Third, by looking into the personality-based mechanisms through which genetics influence entrepreneurship, we can begin to unlock the "black box" of genes (Ilies et al., 2006) and offer a more integrative understanding of the individual-difference antecedents of entrepreneurship (e.g., genetics, personality, and gender) that have, to date, only been examined in isolation. We begin below by exploring the role of gender and personality in entrepreneurship, and developing hypotheses regarding the moderating role of gender and the mediating role of personality in the genetic influences on entrepreneurship.

Gender differences in the heritability of entrepreneurship

Gender differences in the prevalence of entrepreneurship have been studied for decades. Numerous studies show that there is a higher prevalence of entrepreneurship for men than that for women with similar backgrounds (e.g., Brush, 1992; Haber, Lamas, & Lichtenstein, 1987). Additionally, this gender difference tends to be robust across cultures and national boundaries. For example, among Israeli working women, approximately 5.1% are self-employed-entrepreneurs, compared to 15% of Israeli working men (Lerner, Brush, & Hisrich, 1997). Higher prevalence of men's entrepreneurship was also found in Singapore (Kim & Ling, 2001). In the US, women-owned businesses made up only 37% of all sole proprietorships in 1998 (Small Business Administration., 2001). This lower prevalence for women entrepreneurs in various countries indicates a *main effect* of gender on the propensity of people to become entrepreneurs.

In explaining this gender difference in the prevalence of entrepreneurship, a large number of studies demonstrated that women are to some extent discriminated against at various stages of entrepreneurship—a phenomenon also observed in large companies when women managers are evaluated (e.g., Heilman, Block, & Lucas, 1992). Although one study found that once they become entrepreneurs, women may receive favorable perceptions from the general population due to an attributional-augmenting effect (Baron, Markman, & Hirsa, 2001), the vast majority of research suggests that women face more difficulties than their male counterparts in the venturing process. In particular, compared with male entrepreneurs, women entrepreneurs are less likely to seek start-up capital (Fay & Williams, 1993) and angel financing (Becker-Blease & Sohl, 2007), have less financial capital and human capital (i.e., education and quantity of work experience) invested in their start-ups (Boden & Nucci, 2000; Carter, Williams, & Reynolds, 1997), have less access to business clients beyond their traditional household clientele (Bates, 2002), and are asked for more collateral requirements or charged higher interest rates by loan officers (Fraser, 2005; Riding & Swift, 1990). As a result, several large-scale studies on multiple nations revealed that female entrepreneurs are less successful in terms of objective success measures including lower sales, slower growth, and lower profits (Brush, Carter, Gatewood, Greene, & Hart, 2006; Welter, Smallbone, & Isakova, 2006).

This increased level of difficulty for women entrepreneurs may result from the generally-held gender stereotypes against women entrepreneurs (Marlow & Patton, 2005). Research has shown that an entrepreneurial career is typically associated with masculine characteristics (Ahl, 2006; Buttner & Rosen, 1988; Lewis, 2006). Several studies have demonstrated that these gender role stereotypes influence men's and women's intention to pursue an entrepreneurial career (Fagenson & Marcus, 1991; Gupta, Turban, & Bhawe, 2008). These stereotypes may result in female entrepre-

neurs' stronger self-imposed barriers to growth and less favorable perceptions of themselves and the entrepreneurial environment, as compared with male entrepreneurs (Langowitz & Minniti, 2007). Consequently, many women entrepreneurs tend to use entrepreneurship as a means of balancing work and family, rather than achieving financial success (see Bird & Brush, 2002; Brush, 1992; Kepler & Shane, 2007).

Given that the literature shows women entrepreneurs face more environmental challenges and difficulties compared with their male counterparts, we expect that the different venturing environments can result in differential levels of genetic influences on women's and men's tendency to become entrepreneurs. In the following arguments, we draw upon the gene-environmental interaction (G × E) literature, as well as literature exploring gender difference in genetic influences to hypothesize different genetic influences on entrepreneurship across genders.

G × E interactions occur when environmental influences moderate genes' effects on a phenotype or conversely, when the effect of exposure to an environmental stimulus on a phenotype is conditional on a person's genotype (Purcell, 2002). According to the diathesis-stress model of G × E interactions (see Gottesman, 1991; Rende & Plomin, 1992), adverse environments can actually foster greater genetic influences on a behavior of interest. For example, in a supportive environment where everyone has enriched resources, individuals with various levels of genetic endowments towards entrepreneurship may have almost equal probabilities of becoming entrepreneurs due to the abundance of resources and lack of competition for them. Thus, genes should exert very small influences on entrepreneurship when environmental resources are abundant. In contrast, individuals in less supportive or depleted environments do not have that luxury, and would have to rely more upon their genetic endowments to develop their business ideas, set up new ventures, and try to survive in a harsh environment. Thus, in this less supportive situation, genetic factors may play a larger role in impacting people's propensity to engage in entrepreneurial activities.

Behavioral genetics studies on people's positive and negative life events and their social relationships provide support for the logic inherent in the above example. Specifically, researchers found there is very little genetic influence on men's desirable life events but women show a substantial genetic influence on their life events (e.g., major improvements in financial status, making a new acquaintance, etc.; Saudino et al., 1997). Greater genetic effects in negative life events such as interpersonal difficulties, legal difficulties, and financial difficulties were also found for women compared with men, and the difference between the heritability estimates for women versus men on these events were large (differences range from .20 to .49; see Bolinskey, Neale, Jacobson, Prescott, & Kendler, 2004).

The number of social relationships and perceived adequacy of social support also have been shown to have a greater genetic influence among women (Lichtenstein & Pedersen, 1995). In particular, for men the number of social relationships and their perceived adequacy of social support are both impacted by shared-environmental influences, rather than genetic factors (h^2 = .00 for both variables). In contrast, for women both measures are genetically influenced (h^2 = .36 for number of relationships and h^2 = .34 for perceived support; Lichtenstein & Pedersen, 1995). Because successful entrepreneurship is a desirable life event that can result from good social relationships and less interpersonal, legal, and financial difficulties, given the demonstrated gender differences in genetic influences on life events and social relationships, we expect that women would have greater genetic influences on their tendency to become entrepreneurs, as compared with men.

A second reason that we may expect higher genetic influences on women's entrepreneurship is based upon findings regarding differential heritability concerning delinquency behaviors. Using two large samples of adolescent twins, Eley et al. (1999) found higher heritability for non-aggressive delinquent behavior among females (h^2 = .42) than for males (h^2 = .13). With regard to factors influencing non-aggressive delinquent behaviors, their findings suggest that genetic effects have a greater influence on females whereas shared-environment plays a great role for males. Some researchers argue that entrepreneurial activities can be associated with rule breaking and/or deviating from generally accepted social norms (e.g., Gould, 1969). It has been found that there is a longitudinal relationship between adolescents' rule-breaking behavior and entrepreneurship in adult life (Zhang & Arvey, in press). Thus, it seems plausible to expect a higher heritability of entrepreneurship (as a form of deviating behavior) among females than among males. Support for large heritability differences between genders has also been found in studies that have shown that women have higher heritability estimates on behaviors such as stress coping styles (Kato & Pedersen, 2005) and severe DSM-IV major depressive disorder (with men showing zero genetic influence and women showing moderate genetic influence; see Bierut et al., 1999).

In sum, because women are likely to face a more challenging environment for their entrepreneurial endeavors than men, it is likely that gender could moderate the magnitude of genetic influences on entrepreneurship. The adversity that prospective female entrepreneurs face could allow their genetic endowments to strongly influence their entrepreneurship, and the more resource-abundant environment for men may minimize the potential effects of their genetic endowments on their entrepreneurial activities. Thus, we hypothesize that any genetic influence on entrepreneurship will be greater for women than for men.

Hypothesis 1. Compared with men, women will demonstrate a higher level of genetic influence on their propensity to become entrepreneurs.

The mediating role of extraversion and neuroticism

Meta-analytic studies have established that individual differences play a role in the tendencies of people to become entrepreneurs (e.g., Stewart & Roth, 2004; Zhao & Seibert, 2006). Various personality characteristics that have been shown to be related to entrepreneurship have also been linked to genetics. Thus, as White and colleagues (2006, 2007) and Nicolaou and Shane (2009) contend, it makes sense to speculate that one of the mechanisms through which genes influence entrepreneurship is individual personality characteristics. In particular, genes could predispose people to develop personality characteristics that affect their tendency to engage in entrepreneurial activities.

In the current study, we focus on two dimensions in the five-factor model of personality—extraversion and neuroticism—due to two primary reasons. First, research on the biological bases of personality (i.e., brain functioning) has been centering on these two personality variables. For example, Eysenck and colleagues (Eysenck, 1967; Eysenck & Eysenck, 1985) used multiple arousal systems to study extraversion, neuroticism, and psychoticism. In Gray's (1981, 1982) personality theory, behavioral inhibition and activation were used to examine impulsivity and anxiety (which correspond to extraversion and neuroticism, respectively). Overall, among the dimensions of the five-factor model, extraversion and neuroticism have received the strongest support in terms of their association with the differential functioning of distinct neurobiological systems (for a review, see Matthews & Gilliland, 1999). Given the extensive research on the biological basis of these two personality characteristics, we examine extraversion and neuroticism as potential mediators of the genetic influences on entrepreneurship.

By focusing on extraversion and neuroticism we are also able to integrate two personality frameworks that have dominated the personality literature: the five-factor model (Costa & McCrae, 1992) and positive affectivity–negative affectivity (PA-NA, Watson & Clark, 1994; Watson, Clark, & Tellegen, 1988). NA reflects tendencies to experience negative emotional states such as fear, hostility and anger; PA reflects tendencies to experience positive states such as enthusiasm, confidence and cheerfulness. By integrating these two frameworks, Brief (1998) contends that PA-NA may be subsumed under the five-factor framework, with PA being analogous to extraversion and NA to neuroticism. Consequently, examining extraversion and neuroticism can help inform two widely researched personality frameworks.

Extraversion refers to the tendency to be assertive, enjoy the company of other people and large groups, and seek excitement and stimulation (Costa & McCrae, 1992). Researchers have found that extraversion is positively related to occupational interests in terms of enterprising (Costa, McCrae, & Holland, 1984) and to the exploitation of entrepreneurial opportunities (Baron, 2002). It seems logical to expect that extraversion would be an important personality characteristic for a successful entrepreneur since extraverted people tend to have more social skills, and are good at convincing others—an important skill for entrepreneurs when persuading various stakeholders such as venture capitalists, bankers, and customers (Rauch & Frese, 2000; Shane, 2003).

Prior empirical studies have also reported a positive relationship between facets of extraversion and entrepreneurship (e.g., Baron & Markman, 2003; Brandstätter, 1997; Wooten, Timmerman, & Folger, 1999). For example, Babb and Babb (1992) surveyed firm founders and non-founders in various industries and found that founders scored higher on sociability. Roberts (1991) also found that people with firm-founding experience were more extroverted than those who had not started a firm. Based on a large sample from the British National Child Development Study, Burke, FitzRoy, and Nolan (2000) found that anxiety acceptance (a measure of extraversion) assessed at the age of 11 was positively associated with entrepreneurial status and venture performance in adult life. In addition, using meta-analytically derived population correlations (based upon nine effect sizes), Zhao and Seibert (2006, p.265) showed that the standardized regression coefficient for extraversion is .09 ($t = 3.88$, $p < .05$) when entrepreneurial status was regressed upon all the big five personality variables.

The level of social skills has been used as a means of explaining the observed relationship between extraversion and entrepreneurship. The importance of social/political skills in terms of achieving certain job outcomes has been shown in conventional work settings (e.g., Blickle et al., 2008; Harris, Kacmar, Zivnuska, & Shaw, 2007; Liu et al., 2007). Prior research has also reported positive associations between extraversion and the extent to which individuals engage in networking behaviors (e.g., Forret & Dougherty, 2001; Lee & Tsang, 2001). In addition, Totterdell, Holman, & Hukin, 2008 found that people's level of extraversion was positively related to their propensity to connect with others which, in turn, is related to the size of their friendship networks and their centrality in the advice networks. Prospective entrepreneurs' social networks may provide more resources and information needed to discover and exploit opportunities (Aldrich & Zimmer, 1986; Busenitz, 1996; Johansson, 2000) and can lead to better venture performance (Aldrich, Rosen, & Woodward, 1987; Bruderl & Preisendorfer, 1998; Reynolds & White, 1997; Shane & Stuart, 2002). Given the importance of social skills and social networks in the venturing process, these findings provide strong support for proposing a relationship between extraversion and entrepreneurship.

Importantly, not only does extraversion relate to entrepreneurship, but extraversion has also been found to have a strong genetic underpinning (Bouchard & Loehlin, 2001). Using meta-analytic procedures to summarize quantitative genetic studies, Loehlin (1992) showed that extraversion has a heritability of about .49. Moreover, based on molecular genetic analyses, Benjamin et al. (1996) identified the long alleles of the DRD4 exon III repeat gene to be related to extraversion, providing a molecular biological basis for the genetic influences on extraversion.

Based on the above literature, we hypothesize that the genetic influences on entrepreneurship are partially mediated by extraversion. Given the range of possible mediating mechanisms through other channels (e.g., intelligence and other psychological characteristics), and because genes may have a direct effect on entrepreneurship through influencing chemical mechanisms in the brain to increase the likelihood that people become entrepreneurs (Nicolaou & Shane, 2009), we expect a partial mediation role for extraversion.

Hypothesis 2. Extraversion will partially mediate the genetic influences on entrepreneurship.

Neuroticism refers to the tendency of people to be emotionally unstable, and experience negative emotions such as depression, impulsiveness, and vulnerability (Costa & McCrae, 1992). People who are lower in neuroticism tend to be self-confident, calm, and relaxed. Entrepreneurs have to take full responsibility (both financially and personally) for their business and typically work in a dynamic and unstructured environment. Thus, they face high pressures coming from all aspects of the venturing process, as well as the potential for work-family conflicts. It is then reasonable that individuals low in neuroticism would have a better chance of becoming entrepreneurs because they are self-confident and persistent. Conversely, those high in neuroticism would be expected to lack the confidence and resilience required to address the pressures associated with entrepreneurship (e.g., Brandstätter, 1997; Wooten et al., 1999). Zhao and Seibert's meta-analysis (2006, p.265) showed that the standardized regression coefficient for neuroticism was −.12 ($t = 4.80$, $p < .05$) when population correlations among the five factors were used in regression analyses to predict entrepreneurship.

The negative relationship between neuroticism and entrepreneurship can also be partially explained by the enhanced social networks obtained by those low in neuroticism. Klein, Lim, Saltz, and Mayer (2004) found that the level of neuroticism was a key predictor of centrality in advice and friendship networks. In particular, people low in neuroticism tended to obtain central positions in advice and friendship networks and people high in neuroticism tended to become the center of adversarial networks. Because social networks are crucial to the success of potential entrepreneurs, these results suggest that there could be a negative relationship between neuroticism and entrepreneurship.

Similar to extraversion, neuroticism has been found to be highly influenced by genetic factors. Researchers have reported that neuroticism has a meta-analytic heritability estimate of around .41 (Loehlin, 1992). A polymorphism in the 5-HTT gene has been associated with neurotic characteristics (e.g., anxiety, negative emotionality, hostility in unfamiliar situations; Lesch et al., 1996). Given the genetic underpinnings of neuroticism and the relationship between neuroticism and entrepreneurship, we hypothesize that the genetic influences on entrepreneurship will be partially mediated by neuroticism. Partial mediation is hypothesized since there may exist direct relationships and other mediating mechanisms linking genes and entrepreneurship, similar to our arguments above regarding extraversion (Nicolaou & Shane, 2009).

Hypothesis 3. Neuroticism will partially mediate the genetic influences on entrepreneurship.

Method

Sample and procedures

The sample for the current study was drawn from the Swedish Twin Registry (STR) that was established in the late 1950s (for details see Lichtenstein et al., 2002; Pedersen et al., 2002). In 2006, twins in STR who were born in 1959–1985 completed a questionnaire on personality and work-related activities, including entrepreneurship. A total of 1285 pairs of identical (i.e., monozygotic or MZ) twins and 849 pairs of same-sex fraternal (i.e., dizygotic or DZ) twins provided complete data on personality and entrepreneurship measures. In the final sample, 65.7% of the twins are female, all were white, and 40.2% were married. The average age of the sample was 39.0 ($SD = 6.5$). The demographic characteristics of these twins are comparable to those in other countries (e.g., Heath et al., 1997; Johnson & Krueger, 2005). With regard to education, 44.8% of the twins had finished high school and 40.3% of them had associate degrees or college degrees.

Measures

Entrepreneurship

Previous research has employed a variety of operationalizations of entrepreneurship (Nicolaou, Shane, Cherkas, Hunkin, et al., 2008; Nicolaou, Shane, Cherkas, & Spector, 2008). This study used three indicators to measure this variable. Participants were asked: (a) "Do you have a company or partly-own a company at the present time?" (1 = yes; 0 = no), (b) "Have you been mainly self-employed or part-owner in the past three years?" (1 = yes; 0 = no), and (c) "Have you been an employer in the past three years?" (1 = yes; 0 = no). These three indicators were highly correlated in the current study (r's > .91, $p < .001$). We used the average score of the three items when we reported the correlations among study variables. The coefficient alpha was .87 for this three-item scale. In our structural equation models (*SEM*), we used these three indicators to derive a composite measure (which is equivalent to an average score) representing a latent construct, i.e., the propensity of people to become entrepreneurs. A similar latent construct approach has been used by other researchers who investigated the biological basis of entrepreneurship (e.g., Nicolaou, Shane, Cherkas, Hunkin, et al., 2008; White et al., 2006).

Extraversion

Extraversion was measured using a 7-item scale drawn from the abbreviated version of the Eysenck Personality Questionnaire-A (EPQR-A; Eysenck, Eysenck, & Barrett, 1985; France, Brown, & Philipchalk, 1992). Each item was scored 1 (= yes) or 0 (= no). These items include: "Do you like plenty of bustle and excitement around you?," "do you almost always have an answer when spoken to?," "Do you prefer to keep in the background when you are in company with other people?," (reversed), "Do you regard yourself as happy and carefree?," "do you have a lively manner?," "Do you quickly describe your thoughts in words?," and "Do you like to crack jokes and tell funny stories to your friends?" The coefficient alpha was .67 for this scale. To examine the construct validity of this scale, we conducted omnibus confirmatory factor analyses on all items (see below).

Neuroticism

Neuroticism was measured using a 7-item scale drawn from EPQR-A with each item scored 1 (= yes) or 0 (= no). These items include: "Do you worry too much after an embarrassing experience?," "Would you call yourself a nervous person?," "are you a worrier?," "Do you often feel 'fed-up'?," "Do you often worry about things you should not have done or said?," "are your feelings easily hurt?," and "Are you easily hurt when people find fault with you or the work you do?" The coefficient alpha was .78.

Discriminant validity for the self-reported measures was established through individual-level confirmatory factor analyses to verify the distinctiveness of the three constructs, i.e., extraversion, neuroticism, and entrepreneurship. We used all items from the three scales and compared the proposed three-factor measurement model with three alternative two-factor models (combining two measures out of the three) and an omnibus one-factor model. Absolute fit indexes for the proposed three-factor model were adequate, χ^2 ($df = 68$, $N = 4268$) = 941.26, $p < .001$, comparative fit index (CFI = .95, TLI = .96, root-mean-square error of approximation (RMSEA) = .06. These fit indexes were superior to those found for the two-factor models. For the two-factor models, χ^2 ranged from 2306.87 ($df = 52$) to 3964.71 ($df = 50$), CFI ranged from .76 to .84, TLI ranged from .75 to .87, and RMSEA ranged from .10 to .14. The omnibus one-factor model showed the poorest fit, χ^2 ($df = 51$, $N = 4268$) = 5680.48, $p < .001$, CFI = .65, TLI = .65, RMSEA = .16. In combination, these results indicate that our proposed three-factor model provided a better fit to the data than did the alternative models, suggesting the three scales represent concepts that are theoretically and empirically distinct from each other.

Zygosity

Zygosity was measured in the Swedish Twin Registry using twins' answers to the following questions: (a) during childhood, whether you and your twin-partner were as alike as two peas in a pod or not more alike than siblings in general (1 = two peas in a pod, 0 = not more alike than siblings), (b) how often did strangers have difficulty in distinguishing between you and your twin-partner when you were children? (1 = never, 2 = seldom, . . . , 5 = always). This method of zygosity determination has been shown to correctly diagnose more than 95% of the twins in Sweden when compared with blood test results (see Cederlof, Friberg, Jonsson, & Kaij, 1961) and in other countries as well (see Sarna, Kaprio, Sistonen, & Koskenvuo, 1978). This method was also validated using 13 DNA markers based on 199 twin pairs from STR, and proved to be correct in 99% of the twin pairs.

Gender

Twin's gender was assessed based on self-report measures.

Control variables

Twin closeness

The closeness of the two twins of a pair can influence twin concordance on any variable of interest. Thus, it was important in the current study to control for twin closeness when examining the propensity of these twins to become entrepreneurs. We measured twin closeness by asking each individual twin two questions. First, they were asked to indicate how often they have contact with their twin-partner either by telephone, e-mail, or letters (measured as times per year). Second, they were asked how often they meet with their twin-partner (measured as times per year). These two indicators were averaged to obtain a measure of twin closeness. The coefficient alpha was .75 for this scale. To examine the within-pair agreement on twin closeness, we calculated the intra-class correlation (ICC[1]; James, 1982) for this measure using the pair of twins as the level-2 units and the two twins in that pair as level-1 units. ICC(1) was .87, indicating a very high level of agreement between the two twins in a pair.

Other control variables

In addition to twin closeness, marital status (1 = married, 0 = otherwise), education level (1 = compulsory school, 2 = upper secondary school, 3 = high school, 4 = vocational school, 5 = military school, and 6 = university and above), and age (in years) were used as control variables. These variables were controlled for because they may be related to the individual's exposure to entrepreneurial opportunities and their decision to exploit these opportunities (Shane, 2003).

Analysis

We modeled the propensity to engage in entrepreneurship as a latent continuous variable, manifested by a composite measure of the three entrepreneurship indicators. The Mplus program (Muthén & Muthén, 1998–2007) was used to apply genetic model-fitting techniques. Following previous twins research involving ordered categorical dependent variables (e.g., Johnson, McGue, Krueger, & Bouchard, 2004) we used the asymptotically weighted least squares estimator, which does not require normally distributed data.

Univariate analysis on the heritability of entrepreneurship

In the univariate analysis, we used the classic quantitative genetic methodology to estimate the heritability of the tendency of twins to become entrepreneurs. This method utilizes the difference in genetic relatedness between MZ twins (who share all of their genetic material) and DZ twins (who share on average 50% of their genes) to estimate the relative genetic and environmental contributions to the observed variance of a phenotype (in this case, entrepreneurship). Based on behavioral genetics theory, greater similarity between the two members of an MZ twin pair relative to those in a DZ twin pair is indicative of additive genetic contributions.

In the univariate analyses we used multi-group structural equation modeling. In both the MZ and the DZ groups, the variance of the entrepreneurship variable was parsed into three components: additive genetic variance, shared-environmental variance, and non-shared-environmental variance (which also includes measurement error). Additive genetic effects (i.e., latent variable *A*) refer to the effects of the summation of genes across loci, while shared (i.e., latent variable *C*) and non-shared (i.e., latent variable *E*) environmental effects refer to environmental effects that contribute to twin similarities and differences, respectively. The three latent variables (i.e., *A*, *C*, and *E*) are standardized variables, so that their corresponding path coefficients represent the strength of their influences. Fig. 1 shows the path diagram for the univariate model for one group in the multi-group *SEM* analysis. The path coefficients *a*, *c*, and *e* are held equal across the groups.

The structural relationships represented by Fig. 1 can be written as the following structural equations (control variables not shown):

$$P_{ij} = aA_{ij} + cC_{ij} + eE_{ij} \quad (1)$$

$$V_p = a^2 + c^2 + e^2 = 1 \quad (2)$$

where P_{ij} is the measure of entrepreneurship of the ith individual in the jth pair ($i = 1, 2$; $j = 1, \ldots, n$), A_{ij}, C_{ij}, and E_{ij} are standardized latent variables, and their coefficients *a*, *c*, and *e* represent the strength of the additive genetic influence, shared- environmental influence, and non-shared-environmental influence, respectively. V_p is the total variance of the entrepreneurship variable and is typically standardized as having a value of 1. Because *A*, *C*, and *E* are assumed to be independent from one another, V_p can be decomposed to the additive genetic variance (a^2), shared-environmental influence (c^2), and non-shared-environmental influence (e^2). Heritability is estimated as $h^2 = a^2/V_p$.

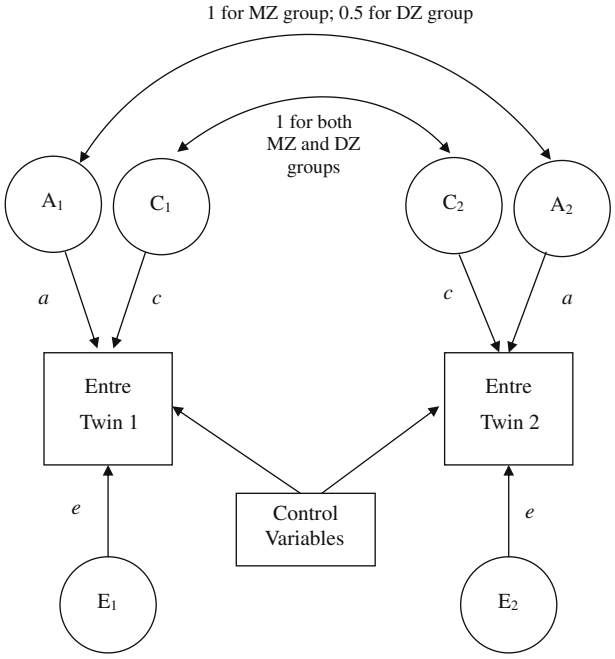

Fig. 1. Univariate genetic model for entrepreneurship. *A*, *C*, and *E* are standardized latent variables representing additive genetic, shared-environmental, and non-shared-environmental influences, respectively. The subscripted numbers (1 and 2) refer to the first and second twin within a pair. *a*, *c*, and *e* are the path coefficients to be estimated and they are constrained to be equal between the MZ and DZ groups. The sum of a^2, c^2, and e^2 is fixed to 1.

We estimated the heritability of entrepreneurship before and after partialling out the control variables including age, marital status, education, and twin closeness. Previous behavioral genetics research has recommended similar approaches to control for confounding factors (e.g., Hakim, Cherkas, Grahame, Spector, & MacGregor, 2004; Nicolaou, Shane, Cherkas, Hunkin, et al., 2008).

Gender's effect on the strength of genetic influences on entrepreneurship was examined by comparing the heritability of entrepreneurship for female versus male twins. A series of nested models were estimated with increased sets of constraints on path coefficients in the MZ group and DZ group. These nested models were compared based on various fit indexes and the most parsimonious model was chosen to test our first hypothesis.

Multivariate analysis for testing mediation

We ran multivariate genetic models to test the potential mediation effects of extraversion and neuroticism. Although mediation can be examined using Baron and Kenny's (1986) multi-step regression-based procedures, the multivariate genetic models can provide a holistic analysis including both mediators simultaneously. In the multivariate models, the two personality variables and the entrepreneurship variable are examined for their respective *A*, *C*, *E* factors and the potential overlap among these factors. If the two personality variables have genetic influences that overlap with those on entrepreneurship, we can conclude that personality variables partially mediate the genetic influences on entrepreneurship.

The multivariate models yield estimates of genetic and environmental contributions to variance in and covariance between the two personality variables and the entrepreneurship variable. Fig. 2 presents a general diagram of the multivariate models we used in this study. For simplicity purposes, this graph only shows the genetic paths. The path coefficients in these models are stan-

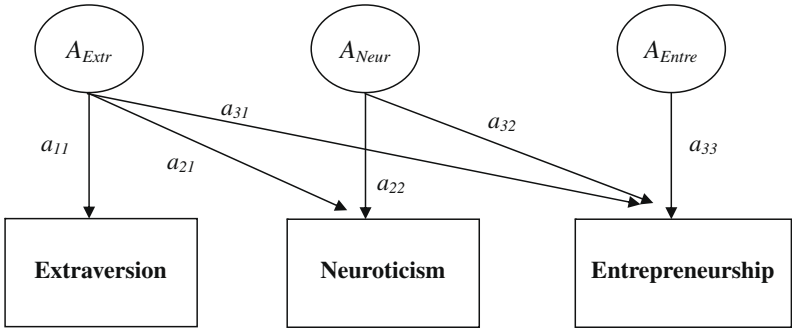

Fig. 2. Multivariate model for testing the mediating effects of extraversion and neuroticism on genetic influences on entrepreneurship. This is a partial diagram, for one twin and for genetic factors only. *A* refers to additive genetic effects. The shared-environmental effects (*C*), non-shared-environmental effects (*E*), and control variables are not shown for simplicity purposes.

dardized partial regression estimates. The effects of the genetic (and environmental) influences on entrepreneurship are decomposed into those specific to entrepreneurship and those in common with the two personality variables. In particular, the path a_{31} and a_{32} represent the genetic influences that are in common with that of extraversion and neuroticism, respectively. The path a_{33} represents the specific or unique genetic factors associated with entrepreneurship. While not shown in the graph, similar sets of paths are estimated for the shared- and non-shared-environmental factors of the two personality variables and the entrepreneurship variable.

This procedure for testing mediation using multivariate quantitative genetic methods approximates the preconditions that Mathieu and Taylor (2007) have identified as critical requirements for mediation inferences: (a) true experimental design, (b) temporal precedence, and (c) theoretical rationale. In particular, the use of twins as study samples takes advantage of a kind of natural experiment where in one condition we have the exact same genetic make-up (i.e., identical twins) and in another condition the make-up approximates 50% (i.e., fraternal twins). Because genes are exogenous to personality characteristics and entrepreneurial activities, and because personality is formed early in life and remains relatively stable across the lifespan, we believe there is temporal precedence of genes and personality before entrepreneurship.

Results

Table 1 provides the comparison between MZ versus DZ twins on the variables used in this study. There were no significant differences in the prevalence of the three entrepreneurship indicators between MZ and DZ twins. However, MZ and DZ twins showed some differences with regards to their martial status (more DZ twins are married; $\chi^2 = 13.24$, $p < .001$), their age (DZ twins are older; $t = -10.4$, $p < .001$), and twin closeness (MZ twins are closer to their co-twins; $t = 19.86$, $p < .001$). These three variables might act as confounds and thus need to be controlled when any genetic influence on entrepreneurship was modeled.

Table 2 reports descriptive statistics and the Pearson product–moment correlations (if both variables are continuous) and tetrachoric correlations (if either variable is categorical) for all of the variables include in this study. All correlations were calculated at the individual level. As shown in Table 2, extraversion ($r = .09$, $p < .001$) and neuroticism ($r = -.06$, $p < .01$) only moderately correlated with entrepreneurship, but these correlations were statistically significant. There was also a significant gender difference in the prevalence of entrepreneurship, as evidenced by the correlation between gender (female = 1, male = 0) and entrepreneurship ($r = -.21$, $p < .001$). Age ($r = .15$, $p < .001$) and marital status ($r = .11$, $p < .001$) were also positively correlated with entrepreneurship.

In order to better present the data structure within the pairs of twins, we provide the within-pair correlations of the two personality variables and the entrepreneurship variable. As shown in Table 3, there was a large difference between female MZ and DZ twins in the within-pair correlation for entrepreneurship ($r = .66$ for MZ and .30 for DZ). In contrast, the correlations were very similar for the male MZ and DZ twins ($r = .54$ for MZ and .58 for DZ twins), indicating a rather small genetic influence on male twins' entrepreneurship.

Table 1
Summary of variables and comparison between MZ versus DZ twins.

Variable	Means			Standard deviations		
	MZ	DZ	χ^2 or *t*-value	MZ	DZ	Levene's test on equal variances
Female (=1, male = 0)	.65	.67	1.17	–	–	–
Married (=1, other = 0)	.38	.44	13.24***	–	–	–
Age (years)	38.2	40.3	−10.4***	6.48	6.27	3.56
Education	5.04	4.92	.94	4.05	4.00	.274
Twin closeness	156.64	94.16	19.86***	110.1	93.8	99.8***
Extraversion	.59	.60	−1.30	.25	.25	.24
Neuroticism	.29	.27	2.34*	.27	.27	.00
Entrepreneurship indicators						
Current business owner	.059	.059	.00	–	–	–
Self-employment/partly owner	.040	.046	−.86	–	–	–
Self-employment	.047	.051	−.28	–	–	–

Total sample size $N = 4268$ (1285 MZ pairs and 849 DZ pairs). Education was measured as an ordered categorical variable with six categories.
* $p < .05$.
*** $p < .001$.

Table 2
Means, standard deviations, and correlations of the variables at the individual level.

	M	S.D.	1	2	3	4	5	6	7	8
1. Female (= 1, male = 0)	.66	.47	–							
2. Married (= 1, other = 0)	.40	.49	.05**	–						
3. Age (years)	39.03	6.48	−.01	.40***	–					
4. Education	4.99	4.03	−.05**	.05**	.04**	–				
5. Twin closeness	131.78	108.31	.16***	−.22***	−.29***	.04**	(.75)			
6. Extraversion	.59	.25	−.10***	.07***	−.01	.05**	.02	(.67)		
7. Neuroticism	.28	.27	.32***	−.11***	−.14***	−.07***	.05**	−.37***	(.78)	
8. Entrepreneurship	.05	.19	−.21***	.11***	.15***	.03*	−.00	.09***	−.06**	(.87)

$N = 4268$. Tetrachoric correlations are reported for categorical variables. Reliabilities are reported in parentheses along the diagonal. Education was measured as an ordered categorical variable with six categories.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 3
Within–pair correlations of the two personality variables and entrepreneurship.

	Female twins						Male twins					
	Twin 1			Twin 2			Twin 1			Twin 2		
	1	2	3	4	5	6	1	2	3	4	5	6
MZ twins												
1. Extraversion (t1)	–						–					
2. Neuroticism (t1)	−.40***	–					−.33***	–				
3. Entrepreneurship (t1)	.03	−.04	–				.14**	−.05	–			
4. Extraversion (t2)	.45***	−.23***	.12**	–			.45***	−.24***	.04	–		
5. Neuroticism (t2)	−.22***	.47***	.02	−.42***	–		−.17***	.36***	−.04	−.35***	–	
6. Entrepreneurship (t2)	−.01	.04	.66***	.11*	−.01	–	.08	.03	.54***	−.03	−.06	–
DZ twins												
1. Extraversion (t1)	–						–					
2. Neuroticism (t1)	−.32***	–					−.28***	–				
3. Entrepreneurship (t1)	.03	.08	–				.05	.17**	–			
4. Extraversion (t2)	.08	.02	−.01	–			.31***	−.12*	.09	–		
5. Neuroticism (t2)	−.02	.09	−.04	−.36***	–		−.10	.09	−.11	−.40***	–	
6. Entrepreneurship (t2)	−.01	.06	.30***	.07	.07	–	.08	.05	.58***	.17**	−.21***	–

For females, there are 836 pairs of MZ and 566 pairs of DZ twins. For males, there are 449 pairs of MZ and 283 pairs of DZ twins. t1 and t2 refer to the first and second twin in a pair.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Hypothesis 1 states that females will demonstrate a greater genetic influence on entrepreneurship than males. Table 4 shows the results based on univariate analysis before partialling out the influences of the control variables. Male and female samples were examined as separate groups in the multi-group *SEM*s. In the full model (Model 1, male *ACE* and female *ACE* model), *A*, *C*, and *E* factors are all included for both gender groups. This model produced a very good fit (CFI = 1.00 and RMSEA = .00). In this model, the heritability estimate of entrepreneurship for males was zero (with a 95% confidence interval including zero), whereas the heritability for females was .65 ($p < .01$, 95% *CI* = .32 to .98). We then tested a nested model in which the genetic influences for males and females were constrained to equality (Model 2). This constrained model showed a statistically significant change in chi-square of 4.34 ($p < .05$, $df = 1$) and the heritability estimates were no longer statistically significant for both genders (point estimate is .25, 95% *CI* = −.11 to .60). This shows the genetic influence on entrepreneurship was significantly different for males versus females.

Another nested model was tested in which both gender groups were specified to have *A* and *E* factors only (Model 3). This model produced a significantly worse fit ($\Delta\chi^2 = 9.68$, $df = 2$, $p < .01$, CFI = .94, RMSEA = .05) in comparison with the full model. Finally, we tested a reduced model where the A component for males and the *C* component for females were constrained to be zero (Model 4). This model showed a non-significant chi-squared change ($\Delta\chi^2 = .01$, $df = 2$) and satisfactory fit indices. Consequently, this male CE and female AE model (Model 4) was chosen as the most parsimonious model to represent the data. Based on this model, males showed no genetic effects on entrepreneurship, with a very strong effect shown for shared-environmental factors ($c = .57$, $p < .001$).

Table 5 provides highly similar results based on analyses after partialling out the effects of the control variables. The constrained model (Model 2), where A_M equals A_F, showed a significant chi-square change and non-significant heritability estimates ($h^2 = .28$, 95% *CI* = −.11 to .67). Model 3 also showed worse fit and a significant chi-square change. In the best-fitting model (Model 4), where the genetic factor for males and the shared-environmental factor for females were fixed to zero, the genetic influences were zero for males and .60 ($p < .001$) for females. Comparing the results before and after partialling out the various control variables, we found a slight decrease in the heritability estimate for females (from .65 to .60). Based on these findings, Hypothesis 1 was supported.

To ensure that we have convergent results, we also performed univariate analyses on each of the three indicators of entrepreneurship both before and after controlling for the various confounding factors. These analyses produced very similar results for each respective indicator. Consequently, we decided to report here only the results for the composite entrepreneurship measure.

Table 4
Univariate analysis results for entrepreneurship, before controlling for age, marital status, education, and twin closeness.

	Males			Females			Fit indexes				
	A_M	C_M	E_M	A_F	C_F	E_F	χ^2	*df*	$\Delta\chi^2$	CFI	RMSEA
1. Male ACE and female ACE model	.00(−.25, .25)	.57**(.29, .84)	.43**(.29, .58)	.65**(.32, .98)	.00(−.25, .25)	.35**(.19, .51)	9.92	13	–	1.00	.00
2. Constrained model $A_M = A_F$	.25(−.11, .60)	.37(.00, .75)	.38***(.25, .52)	.25(−.11, .60)	.36*(.05, .67)	.39***(.22, .57)	14.26	14	4.34*	.99	.01
3. Male AE and female AE model	.64***(.45, .83)	–	.36**(.17, .55)	.65***(.50, .81)	–	.35**(.19, .50)	19.60	15	9.68**	.94	.05
4. Male CE and female AE model[a]	–	.57***(.42, .72)	.43***(.28, .58)	.65***(.50, .81)	–	.35**(.19, .51)	9.93	15	.01	1.00	.00

A, *C*, and *E* refer to the genetic, shared-environment, and non-shared-environment factors, respectively. M and F (subscript) refer to male and female, respectively. Sample consists of 449/283 male MZ/DZ pairs and 836/566 female MZ/DZ pairs. Bootstrapped 95% confidence intervals are reported in parentheses.

* $p < .01$.
** $p < .05$.
*** $p < .001$.
[a] The best-fitting model.

Table 5
Univariate analysis results for entrepreneurship after controlling for age, marital status, education, and twin closeness.

	Males			Females			Fit indexes				
	A_M	C_M	E_M	A_F	C_F	E_F	χ^2	*df*	$\Delta\chi^2$	CFI	RMSEA
1. Male ACE and female ACE model	.00(−.43, .43)	.59**(.22, .95)	.41***(.28, .55)	.58**(.19, .97)	.01(−.31. .34)	.41***(.28, .53)	44.7	65	–	1.00	.00
2. Constrained model $A_M = A_F$	.28(−.11, .67)	.36(−.04, .75)	.36**(.19, .52)	.28(−.11, .67)	.25(−.10, .61)	.47**(.28, .66)	49.6	66	4.9*	1.00	.00
3. Male AE and female AE model	.66***(.48, .84)	–	.34**(.16, .52)	.60***(.42, .78)	–	.40**(.22, .59)	57.03	67	12.3***	.93	.05
4. Male CE and female AE model[a]	–	.59***(.42, .75)	.41**(.25, .58)	.60***(.42, .78)	–	.40**(.22, .59)	44.7	67	.00	1.00	.00

A, *C*, and *E* refer to the genetic, shared-environment, and non-shared-environment factors, respectively. M and F (subscript) refer to male and female, respectively. Sample consists of 449/283 male MZ/DZ pairs and 836/566 female MZ/DZ pairs. Bootstrapped 95% confidence intervals are reported in parentheses. The squared root of A_F in model 3 is .77 ($p < .001$, 95% *CI* = .65 to .89).

* $p < .01$.
** $p < .05$.
*** $p < .001$.
[a] The best-fitting model.

Hypothesis 2 and 3 suggest a mediating role for extraversion and neuroticism in the genetic influences on entrepreneurship. We conducted multivariate analyses for both males and females, although we did not find genetic influences on entrepreneurship in the male twins using univariate models. Possible confounds were also controlled for in the mediation analyses.

Table 6 shows the path coefficient estimates and fit indexes for the full multivariate model and the best-fitting nested models for the female and the male group. For parsimony sake, we only report the paths pointing to the entrepreneurship variable since the paths linking the two personality variables are not the focus of the current investigation.

In the full multivariate model for females, the paths between the shared-environmental factors of the two personality variables and entrepreneurship (i.e., c_{31}, c_{32}, and c_{33}) are very small in magnitude and not statistically significant. After fixing these paths and the path between extraversion's non-shared-environmental factor and entrepreneurship (e_{31}) to zero, we obtained the reduced model that produced a better fit (i.e., AIC dropped from 14.7 to 3.6, RMSEA = .04 rather than .05) and a non-significant change in χ^2. Consequently, the reduced model was chosen for testing mediating effects for the two personality variables. Fig. 3 shows the path coefficient estimates for the reduced model for females.

Based on the reduced model in Table 6 and Fig. 3, extraversion and neuroticism both show some overlap between their genetic factors and that of entrepreneurship. The paths from the genetic factors for these two variables onto entrepreneurship were significant (a_{31} = .09, $p < .05$, 95% CI = .03, .15, and a_{32} = −.12, $p < .05$, 95% CI = −.19, −.06). Thus, both extraversion and neuroticism partially mediated the genetic influences on entrepreneurship for women. Hypothesis 2 and 3 are both supported for women only. The percentage of genetic variance that is mediated by the two personality variables is calculated as the sum of the squared path coefficients for the two personality variables, divided by the sum of the squared path coefficients of all the genetic factors, i.e., $(.09^2 + .12^2)/(.09^2 + .12^2 + .80^2) = 3.4\%$. It is notable that neuroticism also partially mediated the non-shared-environmental influence on entrepreneurship since the path e_{32} is statistically significant (−.04, $p < .05$, 95% CI = −.08, −.01).

In the full multivariate model for males, the path coefficients between the genetic factors of the two personality variables and entrepreneurship (i.e., a_{31}, a_{32}, and a_{33}) were very small in magnitude and not statistically significant. After fixing these paths and the path between extraversion's non-shared-environmental factor and entrepreneurship (e_{31}), neuroticism's shared and non-shared-environmental factors to entrepreneurship (c_{32} and e_{32}) to zero, we obtained the reduced model that produced a better fit (i.e., AIC dropped from 6.9 to .01, RMSEA = .05 rather than .06) and a non-significant change in χ^2. Consequently, the reduced model was chosen for males. Fig. 4 shows the path coefficient estimates for the reduced model for males. According to Fig. 4, extraversion partially mediated the shared-environmental influence on entrepreneurship. In particular, the path from extraversion's shared-environmental factor to entrepreneurship was significant (c_{31} = .17, $p < .05$, 95% CI = .04, .50). The proportion of the shared-environmental variance that was mediated by extraversion was calculated as $.17^2/(.17^2 + .77^2) = 4.6\%$.

Table 6
Testing the mediating role of two personality variables on the genetic and environmental influences on entrepreneurship.

	Genetic paths			Shared-environmental paths			Non-shared-environmental paths			Model fit indexes			
	a_{31}	a_{32}	a_{33}	c_{31}	c_{32}	c_{33}	e_{31}	e_{32}	e_{33}	$\chi^2(df)$	$\Delta\chi^2$	AIC	RMSEA
Female													
Full model	.07*(.02,.19)	−.13*(−.28,−.05)	.79**(.68,.82)	.03(−.11,.15)	.00(−.19,.18)	.00(−.14,.14)	.03(−.03,.07)	−.04*(−.08,−.01)	.58**(.55,.62)	62.7(24)	–	14.7	.05
[a]Reduced	.09*(.03,.15)	−.12*(−.19,−.06)	.80**(.77,.82)	–	–	–	–	−.04*(−.08,−.01)	.58**(.55,.62)	65.6(31)	2.9	3.6	.04
Male													
Full model	.07(−.22,.30)	−.06(−.18,.07)	.01(−.19,.19)	.12*(.01,.71)	−.03(−.51,.57)	.67**(.36,.89)	−.01(−.06,.05)	−.07(−.11,.03)	.60**	54.9(24)	–	6.9	.06
[a]Reduced	–	–	–	.17*(.04,.50)	–	.77**(.64,.89)	–	–	.62**(.58,.66)	64.0(32)	9.1	.01	.05

95% confidence intervals are reported in parentheses. *a*, *c* and *e* refer to the coefficients of the paths from the genetic, shared-environmental, and non-shared-environmental factors to the entrepreneurship variable, respectively; Subscripts *31* and *32* indicate that the paths come from extraversion and neuroticism, respectively. Subscript 33 indicates that the path represents specific factors associated with entrepreneurship.

* $p < .01$.

** $p < .05$.

[a] The best-fitting model.

Discussion

Based on a large sample of MZ and same-sex DZ twins from the Swedish Twin Registry, we used quantitative genetic methods to examine the genetic influences on the propensity of these twins to become entrepreneurs. For both males and females, we estimated the genetic, shared-environmental, and non-shared-environmental factors that influence the propensity to become entrepreneurs. We found highly different heritability estimates for males versus females. Females show a high heritability and zero shared-environmental influences on their propensity to become entrepreneurs ($h^2 = .60$, after partialling out potential confounds). The magnitude of this heritability estimate is even higher than those typically found with personality variables (e.g., Loehlin, 1992). In contrast, entrepreneurship in males was not shown in the current sample to be heritable, with a substantial effect of shared-environment on entrepreneurship. Additionally, results based on mediation analyses indicated that extraversion and neuroticism serve as partial mediators in the genetic influences on the propensity of females to become entrepreneurs—a result that replicates and extends previous research on the mediating effect of sensation-seeking (a facet of extraversion) on entrepreneurship (see Nicolaou, Shane, Cherkas, Hunkin, et al., 2008; Nicolaou, Shane, Cherkas, & Spector, 2008). The proportion of mediated genetic influences on females' entrepreneurship was 3.4%. For males, extraversion serves as a partial mediator in the shared-environmental influences on entrepreneurship and the proportion of the mediated shared-environmental variance was 4.6%. Apparently, the common environment (e.g., family and common upbringings) for male twins can influence their extraversion which, in turn, may influence their propensity to engage in entrepreneurial activities.

Although females show a high degree of heritability for entrepreneurship, our results do not indicate that genes determine entrepreneurship. As Plomin, DeFries, and McClearn (1990, p. 376) posit, genetic influences on a behavior indicate "probabilistic propensities rather than hard-wired patterns of behavior." For the females, 40% of the variance in entrepreneurship was still explained by unique environments and experiences. For males, we found strong evidence of the shared-environmental effects on their tendency to become entrepreneurs and the magnitude of shared-environmental influences on men's entrepreneurship was about the same as that of the genetic influences on women's entrepreneurship.

As suggested in our introduction, based on the diathesis-stress model in behavioral genetics (see Gottesman, 1991; Rende & Plomin, 1992), adverse environments may foster higher genetic influences on the behavior of entrepreneurship. With respect to explaining the results of the current study, it is possible that such adverse environments may exist both in the home as well as outside the home in a variety of forms including gender role stereotypes. Given the birth cohorts that our samples of twins came from, it is possible that the twins' parents did not set positive expectations for female twins to become entrepreneurs. Such expectations may be a function of societal expectations that to be an entrepreneur during that period in Sweden's history, it was important to be a male. Thus, females may have needed to overcome both an internal and external stressful environment to become entrepreneurs, potentially accounting for the dramatic differences in heritability between males and females in the present study.

Theoretical contributions

Our findings confirmed previous research which, based on a predominately female sample, found that the tendency of women to become entrepreneurs is heritable (Nicolaou, Shane, Cherkas,

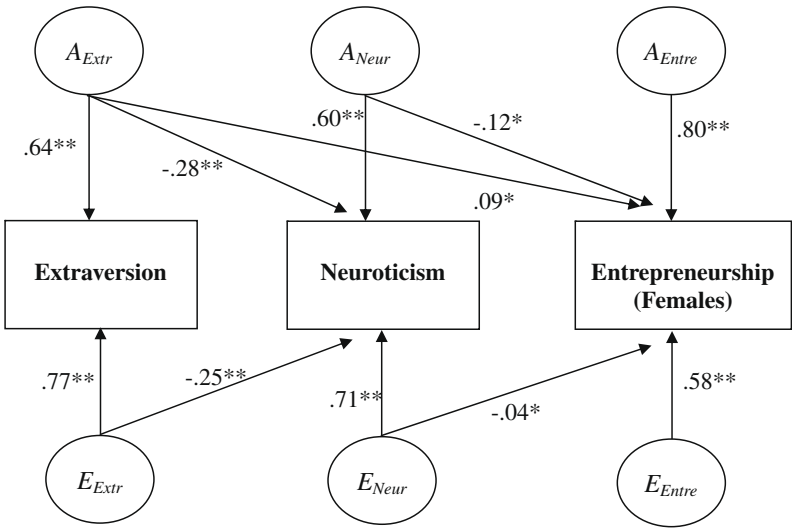

Fig. 3. The mediating effects of extraversion and neuroticism on genetic influences on entrepreneurship (female twins only). This is a partial diagram for one twin only. *A* and *E* refer to additive genetic and non-shared-environmental effects, respectively. Control variables are not shown for simplicity purposes. $^{*}p < .05$, $^{**}p < .01$. Standardized path coefficients are reported.

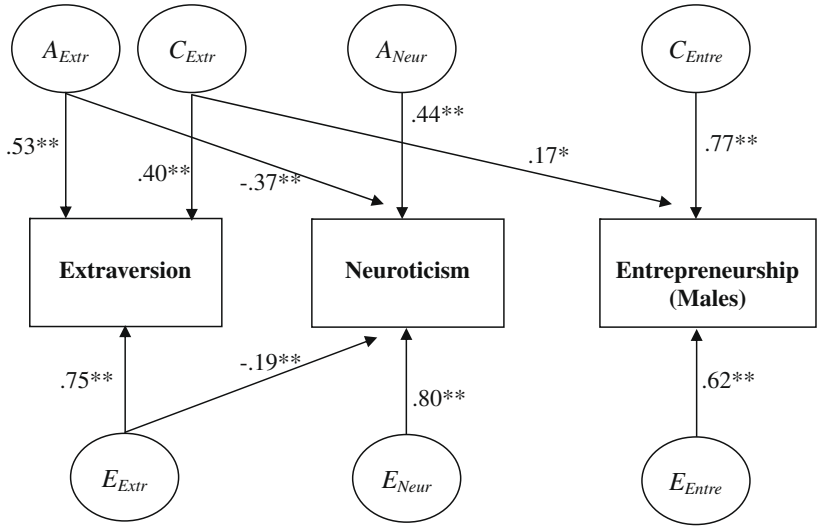

Fig. 4. The mediating effects of extraversion on shared-environmental influences on entrepreneurship (male twins only). This is a partial diagram for one twin only. *A*, *C*, and *E* refer to additive genetic, shared-environmental, and non-shared-environmental effects, respectively. Control variables are not shown for simplicity purposes. $^{*}p < .05$, $^{**}p < .01$. Standardized path coefficients are reported.

Hunkin, et al., 2008). Extending this line of research, we find substantial gender differences in the heritability of entrepreneurship. These findings highlight the value of research on female entrepreneurs and provide an alternative framework to reconcile the differences in the prevalence of male versus female entrepreneurs observed in existing literature (see Brush, 1992; Jennings & McDougald, 2007). Extant research on female versus male entrepreneurs often investigates "surface-level" differences such as education level, capital investment, and work-family responsibilities. Our finding suggests that researchers need to incorporate more "deep-level" biological differences (such as genetic differences) in order to better understand variation across genders in entrepreneurial outcomes.

This study also contributes to the entrepreneurship literature by pointing out the gender-specific mechanisms that shared-environments may have on children's tendency to become entrepreneurs. While prior research suggests that parents' entrepreneurship promotes children's probability to become entrepreneurs (Aldrich & Kim, 2007; Sorenson, 2007), the intergenerational transmission of such influences may work through different channels for female versus male children. The fact that males have shared-environmental influences, but not genetic influences, on their tendency to engage in entrepreneurial activities indicates that being raised in the same household increases the similarity of male siblings in their tendencies to engage in entrepreneurial activities. This may be due in part to the higher likelihood of their father's being entrepreneurs, and offering a home-based model for the male twins to emulate. Alternatively, our results indicate that the primary transmission mechanism for females might be through the entrepreneurship-related genetic factors directly passed from parents to children, while males are more influenced by shared environments. Thus, our study provides a new perspective on the gender-specific nature of the genetic influence on entrepreneurial activities.

We found a mediating role for extraversion and neuroticism in the genetic influences on women's entrepreneurship and for extraversion in the shared-environmental influences on men's entrepreneurship. These results highlight the value of individual differences in entrepreneurship research. Researchers interested in explaining the propensity of people to become entrepreneurs have obtained mixed findings when examining the role of individual differences in entrepreneurship and have often turned to look at situational variables as primary antecedents (e.g., Gartner, 1988; Shaver & Scott, 1991). Turning to this strategy coincides with a tendency among prior researchers to abandon the "individual entrepreneur" as a means of studying entrepreneurship (see Mitchell et al., 2002). As Cogliser and Brigham (2004) argued, this is like "throwing the baby out with the bathwater". In the world of business, practitioners and venture capitalists have continued to consider the individual entrepreneur to be critical to the success of a new venture (Shane & Venkataraman, 2000; Stuart & Abetti, 1990).

To reconcile the discrepancies that have emerged in terms of prior research streams in the entrepreneurship literature, our findings offer an alternative direction for future research to integrate situational and individual-difference antecedents in explaining entrepreneurship. In particular, although males in the Swedish sample have only environmental influences on their propensity to become entrepreneurs, females were shown to have non-shared-environmental and genetic influences and these genetic influences appear to be partially carried through personality variables such as extraversion and neuroticism. Consequently, future entrepreneurship research may need to pay differential attention to individual and environmental variables when different gender groups are examined.

Practical implications

Prior research has long established the importance of family environment in fostering entrepreneurship. Our findings that family environment plays a critical role in predicting males' (but not females') propensity to become entrepreneurs has important implications for informal and formal education on entrepreneurship. These results confirmed prior arguments for differential reasons and processes for men and women to become entrepreneurs (e.g., Shane, 2003). Given the adversity that female entrepreneurs face both within the home and potentially outside in communities and organizations, educators and policy makers may take measures to eliminate or reduce the obstacles and promote more equal support for both gender groups. Furthermore, as more women emerge as entrepreneurs around the world, the more likely parents will realize that their daughters can grow up some day and run a successful business. We believe that the home environment could set positive self-fulfilling prophecies in motion early on in regards to what females should be doing in terms of entrepreneurial careers, especially when more mothers become entrepreneurs. With the cohort of twins examined in the current study, the more "adverse" environments may have provided greater opportunities for heritability to account for entrepreneurship among females.

Researchers have shown that gender stereotypes negatively influence the perceptions and evaluations of women leaders (e.g., Heilman, Martell, & Simon, 1988; Heilman, Wallen, Fuchs, & Tamkins, 2004; Schein, 2001). However, in a recent study conducted by Duehr and Bono (2006), the authors reported that the stereotypes that have traditionally differentiated male and female managers/leaders have diminished in their impact over the last 15 years, with this research showing a greater tendency for managerial and leadership roles to be seen as more communal or in line with a "female leadership style". We suspect that the changes occurring in terms of perceptions of female characteristics and leadership roles may parallel those with entrepreneurship. If that were the case over time, we might then find a greater impact attributable to early environmental effects such as parenting expectations and role modeling.

This study identified two personality characteristics extraversion and neuroticism as mechanisms through which genetic factors influence the tendency to become an entrepreneur for females. In addition, extraversion also mediated the shared-environmental influences on men's entrepreneurship. These findings reconfirmed the importance of individual differences—especially extraversion—in the venturing process and have implications for the selection decisions for corporate venturing and the funding decisions on start-ups. Corporate management and funding institutions can select potential intrapreneurs and entrepreneurs (both male and female) based on their enduring individual differences (e.g., extraversion).

Limitations

Like all research using twin samples, our study has limitations. The most important limitation centers on issues of generalizability. Our sample is constrained to white female and male twins in Sweden. Although this method rules out the effects of extraneous factors associated with different cultures and racial groups with regard to entrepreneurship, the generalizability of our results to other groups and cultures requires further investigation. Within our sample, we are fortunate to have relatively heterogeneous individuals in terms of age, educational levels, marital status, and closeness of the twins. This heterogeneity might help mitigate the concerns raised above regarding the generalizability of our findings, but the homogeneity of culture and race in our sample is nevertheless an important limitation that future research needs to address.

Second, like many studies in behavioral genetics, we assume the absence of assortative mating, which refers to a situation where people with similar characteristics (e.g., being entrepreneurial or extraverted) tend to mate. Assortative mating decreases the range of variation on a specific phenotype and, thus, results in an overestimate of heritability of that phenotype.

Third, our cross-sectional data on entrepreneurship and personality variables are not appropriate for studying genetic influences on the survival or the performance of new ventures. Thus, this study only examined the propensity to become entrepreneurs, rather than the performance of ventures or other aspects of entrepreneurship. Moreover, we operationalized entrepreneurship as a composite measure of self-employment and company ownership. Although prior research used a similar operationalization (see Evans & Leighton, 1989), there remains a lack of consensus on the definition of entrepreneurship in the literature. Future research could follow a sample of twins over time and collect multiple measures of entrepreneurship and venture performance data repeatedly across multiple time periods. Using this strategy would help test the generalizability our results to other ways of defining entrepreneurship and venture performance.

Fourth, our measure of extraversion had an internal consistency estimate that was on the borderline ($\alpha = .67$). This is probably due to the dichotomous nature of the items in the scale. We thus conducted omnibus CFAs to demonstrate the discriminant validity for the two personality measures and the entrepreneurship variable. The CFA results provided strong support for the distinctiveness of the three constructs and may alleviate some concerns on the relatively low reliability of the extraversion measure.

Lastly, the current study did not explicitly examine any potential interactions between the environment and genetic influences on entrepreneurship. Our estimates of the heritability for male and female twins can be considered an average heritability estimate across all levels of a particular environmental variable

(Purcell, 2002). Future research could examine environmental harshness as a potential moderator of the genetic influences on entrepreneurship. Specifically, researchers can measure environmental harshness as perceived by male and female twins during their formative years and investigate whether the magnitude of genetic influences is moderated by environmental harshness.

Conclusions

In conclusion, our study sheds new light on research regarding individual differences and entrepreneurship, research which seems to have fallen out of favor in the last few decades. Our results demonstrate the importance of genetic and shared-environmental factors in predicting the propensity of males and females to become entrepreneurs. We found that extraversion and neuroticism play a modest, yet statistically-significant mediating role in the genetic influence on females' tendency to become entrepreneurs. We hope our study will inspire additional research examining the antecedents of entrepreneurship, while taking into consideration biological determinants. Endeavors along this line can hopefully provide valuable information that will aid policy makers in promoting strategies to encourage entrepreneurship. Our research may also provide guidance to future entrepreneurs that such individuals appear to be "both born and made".

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