



THE INFLUENCE OF SENSATION SEEKING IN THE HERITABILITY OF ENTREPRENEURSHIP

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This study examined the influence of genetic factors on the tendency to engage in entrepreneurship. We found that, in the particular sample we examined, between 37 and 42 percent of the variance in the tendency of people to engage in entrepreneurship is accounted for by genetic factors. A substantial part of this variance was mediated by the psychological trait of sensation seeking, suggesting that genes affect the tendency of people to engage in entrepreneurship by affecting the distribution of sensation seeking across people. Copyright © 2008 Strategic Management Society.

INTRODUCTION

One of the central questions in the field of entrepreneurship is: who becomes an entrepreneur? For at least four decades, researchers have examined this question (Gartner, 1988; Bird, 1989; Shane and Venkataraman, 2000; Aldrich and Martinez, 2001; Baron, 2004). While this effort has identified a variety of factors that influence this decision (see Shane, 2003, Chapters 4 and 5 for a review), one of the most interesting explanations for the tendency of people to become entrepreneurs—genetic factors—has not been examined. This article seeks to fill this void by introducing an argument for the role of genetic factors into the discussion.

Specifically, we build on one of the oldest traditions in the entrepreneurship literature to argue that

genetic factors affect the probability that people will possess an endowment of individual differences that, in interaction with environmental stimuli, increases the likelihood that they become entrepreneurs. Although some researchers have criticized the individual differences perspective (e.g., Gartner, 1988; Aldrich, 1990), the extant literature shows that who becomes an entrepreneur is correlated with a variety of psychological attributes, such as need for achievement (McClelland, 1961; Begley and Boyd, 1986), overconfidence (Busenitz, 1999), locus of control (Evans and Leighton, 1989; Cromie and Johns, 1983), optimism (Cooper, Woo and Dunkelberg, 1988), and risk-taking propensity (Begley and Boyd, 1987; Stewart and Roth, 2001). Moreover, several rigorous meta-analytic studies have shown significant patterns in support of this perspective (Collins *et al.*, 2004; Rauch and Frese, 2000; Stewart and Roth, 2004; Baum, Frese, and Baron, 2007).

Missing from the discussion of the individual difference perspective on entrepreneurship has been an explanation for the source of variation across people in their endowment of these individual

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differences. We propose that genetic factors account, at least in part, for the variation in the endowment of these individual differences across people, given the evidence that many psychological attributes are influenced by genes (Benjamin, Ebstein, and Belmaker, 2003; Plomin and Walker, 2003; DiLalla, 2004), including personality (Ebstein *et al.*, 1996; Benjamin *et al.*, 1996) and attitudes (Bouchard *et al.*, 2004).

We posit that the personality trait of *sensation seeking* increases the likelihood that a person will choose an occupation that causes them to bear risk in the pursuit of novelty. This is because their genetic composition gives them higher arousal thresholds for experiencing physiological sensations from undertaking these activities. Because starting one's own business is one of those occupations that leads people to bear risk in the pursuit of novelty, a genetic endowment that leads some people to be more sensation seeking than others also leads them to be more likely than other people to start their own businesses. We empirically test two hypotheses that follow from this argument: (1) A substantial portion of the variance in who becomes an entrepreneur is, partly, endogenously determined by a person's genetic composition; and (2) genetic factors operate, at least in part, through covariance with the individual difference of sensation seeking.

Understanding the role of genetic factors in influencing the tendency of people to engage in entrepreneurship is important because it will improve both theoretical and empirical research on the topic. First, understanding the role of genetic factors might help us gain a better understanding of why people become entrepreneurs. Recently, management researchers have tended to focus on situational factors to answer this question (Thornton and Flynn, 2003; Aldrich and Wiedenmayer, 1993; Gartner, 1988), leading some scholars (e.g., Stewart and Roth, 2001; Baron, 2002; Shane and Khurana, 2003; White, Thornhill, and Hampson, 2006, 2007) to believe individual differences have been insufficiently considered. Research on genetic factors might help us gain an accurate understanding of the interaction between individual differences and situational factors by showing how genetic factors affect the probability of developing individual differences that increase the tendency to engage in entrepreneurial activity.

Second, consideration of the role of genetic factors may help researchers conduct better empirical entrepreneurship research. For instance, by specifying the role of genetic factors in the tendency of people to

engage in entrepreneurial activity, researchers would be better able to identify the appropriate comparison group to test the effect of environmental factors. This would permit more precise tests and, possibly, reveal patterns that have not been shown empirically, but have been posited theoretically. Similarly, by specifying the role of genetic factors, researchers can determine if the observed association between individual differences and the tendency of people to engage in entrepreneurial activity are artifacts of omitted variable bias because both are endogenously affected by genetic factors.

We employ the methodology of behavioral genetics, which holds that researchers can compare monozygotic (MZ) and dizygotic (DZ) twins¹ to determine if genetic factors influence the propensity of people to engage in an outcome of interest. Because MZ twins share all their genetic composition and DZ twins share, on average, half of their segregating genes, differences in the concordance between entrepreneurial activity of MZ and DZ twins can be attributed to genetic factors, if one assumes that shared environmental factors are not systematically different for MZ and DZ twin pairs.² By examining the genetic predisposition to entrepreneurship and sensation seeking, we can determine whether entrepreneurship is heritable and, if so, whether sensation seeking mediates this heritability.

BOUNDARY CONDITIONS

Before we turn to an explanation of our theory, we provide some boundary conditions on our effort. First, we are *not proposing* that genes *determine* who engages in entrepreneurial activity because genetic factors do not *cause* people to engage in social activities. Rather, we are proposing that people with a certain genetic composition have a higher probability of becoming entrepreneurs because they are more likely to be sensation seekers. As Plomin, DeFries,

¹In common parlance, monozygotic twins are identical twins and dizygotic twins are fraternal twins.

²Identical twins are formed when a single sperm fertilizes a single egg, which then splits to form two embryos. Because identical twins are formed from the same egg and the same sperm, they receive exactly the same genes from their parents. Fraternal twins are formed when two sperm fertilize two eggs at the same time, resulting in two embryos. Because fraternal twins can each get a particular variant of a gene from either their mother or their father, on average, they have half the same genetic composition.

and McClearn (1990: 376) explained, 'Genetic effects on behavior are not deterministic in the sense of a puppeteer pulling our strings. Genetic influences imply probabilistic propensities rather than hard-wired patterns of behavior.'

Second, we also are *not* suggesting that there is a specific gene for entrepreneurship. Entrepreneurship is a complex phenotype,³ and it is very unlikely that there is a strong association between one particular gene and the tendency to engage in it. Moreover, the relationship between specific genes and the tendency to engage in entrepreneurship is likely to be quite complex, given the length of the causal chain from genes to entrepreneurial activity. Rather, we propose that the effect of genes on sensation seeking is likely to be epistatic; multiple genes may *interact* with each other in order to increase the *likelihood* for a person to be sensation seeking (Wolf *et al.*, 2000; Grigorenko, 2003). This combination of genes influences the propensity of people to become entrepreneurs by partially affecting the distribution of the endowment of sensation seeking across individuals.

Third, we are not arguing that the genetic factors that affect the probability that some people become entrepreneurs are unique to entrepreneurship. Rather, we propose that these genetic effects are pleiotropic—the genes that influence one social behavior can also influence another (Plomin *et al.*, 2001). The pleiotropic effect of genes means that those genes which increase the propensity of people to engage in entrepreneurship also increase the propensity of people to engage in other activities. In the specific mechanism we are examining empirically, those genes which combine to make people more sensation seeking will increase the probability that people engage in all activities which sensation seeking affects, whether that is to become an entrepreneur, play high-risk sports (Jack and Ronan, 1998), engage in physical and verbal aggression (Joireman, Anderson, and Strathman, 2003), drive drunk (Arnett, 1990), and so on.

Fourth, we believe that environmental factors also affect the tendency of people to become entrepreneurs. Specifically, a person's endowment of sensation seeking, which is affected by their genetic

composition, interacts with exogenously determined environmental factors that affect the amount of information about entrepreneurial opportunities they receive. In fact, these environmental factors have a large effect on defining the phenotype that is affected by the pleiotropic effect of the genes.

Fifth, we propose that the mechanisms that we examine are the same regardless of the operationalization of entrepreneurship (i.e., self-employment, firm formation, business ownership, etc.), and explicitly examine the level of convergence between these different operationalizations of entrepreneurship.

THEORY DEVELOPMENT

The extant literature shows that who becomes an entrepreneur is correlated with a variety of psychological attributes, such as need for achievement (McClelland, 1961; Begley and Boyd, 1986), overconfidence (Busenitz, 1999), locus of control (Evans and Leighton, 1989; Cromie and Johns, 1983), optimism (Cooper *et al.*, 1988), and risk-taking propensity (Begley and Boyd, 1987; Stewart and Roth, 2001, 2004). However, little empirical research has examined whether genetic factors lead people to develop psychological attributes which predispose them to become entrepreneurs, despite the evidence that many psychological attributes are influenced by genes (Benjamin *et al.*, 2003; Plomin and Walker, 2003; DiLalla, 2004), including personality (Ebstein *et al.*, 1996; Benjamin *et al.*, 1996) and attitudes (Bouchard *et al.*, 2004). The lack of evidence notwithstanding, it is quite plausible that genes lead some people (and not others) to develop psychological attributes that affect the probability they will become entrepreneurs.

The mechanism through which this happens is straightforward. Genes provide instructions for the creation of proteins out of amino acids. If a gene that codes for the creation of a particular protein is missing, then the chemical reaction that it is designed to facilitate will not occur as efficiently. If that chemical reaction controls brain activity, it can influence the development of individual attributes that affect behaviors, such as the tendency of people to become entrepreneurs (White *et al.*, 2006, 2007).

One genetically-influenced individual attribute that could influence the tendency of people to engage in entrepreneurship is sensation seeking, a personality trait that creates a need for novel experiences

³ A *genotype* is the genetic composition that leads to a *phenotype*, or the observed set of characteristics of the organism. In our case, the *genotype* is the (unobserved) combination of genes that influences the tendency of people to engage in entrepreneurship. The *phenotype* is the observed behavior of entrepreneurship or something else.

(Zuckerman, 1994; Stephenson *et al.*, 2003). People who are sensation seeking search out change and novelty (Sjoberg and Engelberg, 2006) and approach new situations more positively and with less apprehension than other people (Joy, 2004). They have ‘an aversion to repetition and routine’, like ‘lots of change and excitement’ and ‘enjoy getting into new situations.’ (Zuckerman, Eysenck, and Eysenck, 1978; Zuckerman, 1994).

People high in sensation seeking are more willing than people low in sensation seeking to take risks to achieve the sensations they get from doing new things (Lusher, Ebersole, and Ball, 2000), and are less likely to perceive risks (Weber *et al.*, 2002; Rosenbloom, 2003). As a result, people high in sensation seeking have a preference for higher risk/higher reward choices, particularly in situations in which making decisions depends on both risk and skill (Zuckerman, 1994), because they tend to value the rewards from high-risk activities more and the risks less than low sensation seekers (Rosenbloom, 2003).

The willingness to bear the risks associated with starting a business is likely to be affected by sensation seeking because ‘risk taking can be any behavior that has a significant degree of uncertainty about losses associated with its outcome’ (Rosenbloom, 2003: 375). In fact, studies have shown that high sensation seekers are more likely than low sensation seekers to engage in a variety of risky activities that are related to starting a business, including taking jobs which involve risk bearing (Rosenbloom, 2003), and bearing personal financial (Wong and Carducci, 1991) and career risk (Zuckerman, 1994).

Entrepreneurship is an activity that involves the bearing of risk from the pursuit of novelty (Shane, 2003). Regardless of the type of business a person starts, whether it is a new restaurant or a biotechnology firm, when a person starts a new business he or she engages in novel activity. The person needs to create a product or service to offer to customers, identify and attract those customers, and establish an organization to provide the product or service. This pursuit of novelty involves risk because an entrepreneur is the residual claimant on profits from his or her business, and is compensated only if revenues exceed costs (Khilstrom and Laffont, 1979). Because an entrepreneur cannot know in advance that the business will be profitable – the costs of creating the new business need to be incurred before the entrepreneur will know if the effort to create a new product (or service), attract customers, or set up the

organization will be successful (Knight, 1921) – the entrepreneur stands to lose the financial resources and time (opportunity cost) that were invested in the entrepreneurial effort if he or she is not successful.

Genetic factors may lead high sensation seekers to be more likely to start businesses than low sensation seekers through the following physiological mechanism: Sensation seeking has a biochemical component (Zuckerman, 1983); high sensation seekers have low levels of the enzyme monoamine oxidase (MAO), which metabolizes neurotransmitters⁴ like norepinephrine and dopamine (Zuckerman, 2004). When people are in a high risk situation, they often experience anxiety that keeps them from undertaking risky activity because the body produces neurotransmitters like norepinephrine and dopamine. However, when high sensation seekers are faced with the opportunity to engage in a risky action in pursuit of novelty, they are less likely than low sensation seekers to experience the anxiety which keeps them from engaging in that activity because their bodies produce less MAO, leading them to have less dopamine and norepinephrine in their systems (Rosenbloom, 2003). Because high sensation seekers have less dopamine and norepinephrine in their systems, they have a sense of arousal generated by the novelty that exceeds the discomfort with the risk, which makes them more likely to act to pursue novelty in situations that involve taking risks (Rosenbloom, 2003).

Research has shown that there is a genetic basis to sensation seeking. First, behavioral genetics studies have shown that sensation seeking is heritable (Cloninger, Adolfsson, and Svrakic, 1996; Hur and Bouchard, 1997; Koopmans *et al.*, 1995), with estimates indicating that it is as high as 58 percent (Fulker, Eysenck, and Zuckerman, 1980; Zuckerman, 2004). Second, molecular genetics studies have found that people higher in a particular allele of the DRD4 gene are more likely than others to be sensation seeking (Ebstein *et al.*, 1996). Moreover, studies have shown that people who had this particular allele of the DRD4 gene *combined* with a polymorphism of the DRD2 gene were more likely than people who only had one of these genes to exhibit novelty seeking behavior (Noble *et al.*, 1998).

Researchers believe the DRD4 gene affects sensation seeking by influencing the release of neurotransmitters,

⁴A neurotransmitter is a chemical that is used to relay and modulate signals between a neuron and a cell.

such as dopamine and norepinephrine, in the central nervous system (Geen, 1997; Van Tol *et al.*, 1991, 1992). Because high sensation seekers have greater physiological arousal than low sensation seekers when stimuli are new (Zuckerman, 2004), researchers believe people with particular alleles of the DRD4 gene have different arousal thresholds in response to stimuli. These arousal thresholds mean that sensation-seeking individuals need to pursue more novelty through riskier actions to reach the threshold of stimulation necessary to release neurotransmitters, such as dopamine, that provide the desired physiological response (Linnet *et al.*, 2006). The result is that people with different genetic compositions behave differently on the domain of sensation seeking. High sensation seekers are more likely than low sensation seekers to bear risk in the pursuit of novelty through activities—such as starting businesses—because the greater stimulus is necessary for them to get an equivalent physiological response.

In short, we hypothesize the following:

Hypothesis 1: Entrepreneurial activity is heritable.

Hypothesis 2: The heritability of entrepreneurial activity is partially mediated by sensation seeking.

METHODOLOGY

Twin studies

The natural experiment of twins allows us to measure whether there is a genetic predisposition in the tendency of people to engage in entrepreneurial activity. The experiments are based on comparison of monozygotic (MZ) twins, who are created when a single sperm fertilizes a single egg, and are 100 percent genetically identical, and dizygotic (DZ) twins, who are created when two separate eggs are fertilized by two separate sperm, and share, on average, 50 percent of their segregating genes.

Examining the similarity and difference in entrepreneurship between the two types of twins provides insight into the proportion of variance in entrepreneurship that is explained by genetic factors. If genetic factors are important for entrepreneurship, then MZ twins, who share all their genetic make-up, must be more similar than DZ twins, who share only 50 percent of their segregating genes. However, if the tendency to engage in entrepreneurship is

explained solely by environmental factors, then no difference in the similarity between MZ and DZ twins in entrepreneurship should be observed.

Twin studies depend on the assumption that MZ and DZ twins experience equivalent shared environments. For violation of this assumption to occur, environmental factors must treat MZ twins more similarly than DZ twins *and* the similarity in treatment must make a difference to the phenotype under study. MZ twins having more similar experiences than DZ twins *because* they are more similar genetically does not constitute a violation of the equal environments assumption because the differences are not caused environmentally (Plomin *et al.*, 2001). The equal environments assumption has been tested extensively and many sources now confirm the robustness of this assumption (Scarr and Carter-Saltzman, 1979; Bouchard and Propping, 1993; Kendler *et al.*, 1993; Hettema, Neale, and Kendler, 1995; Carey, 2003). Studies of MZ and DZ twins reared together and apart have shown that the MZ twins reared apart are consistently more similar than both DZ twins who are reared together and DZ twins who are reared apart (Bouchard, 1998; Bouchard *et al.*, 1990). In addition, studies of twins reared apart and together and studies of biologically unrelated people reared in the same household have shown that the rearing environment explains only a small part of variance in most social outcomes (Bouchard *et al.*, 1990; Plomin and Daniels, 1987). Furthermore, many parents tend to randomize the environmental treatment of their children. Some are misinformed or make erroneous evaluations about the zygosity of their twins, leading some parents to raise their DZ twins as MZ twins and other parents to treat their MZ twins as DZ twins. Some parents accentuate the similarity of their DZ offspring by making certain that they wear the same clothes and have the same hairstyles, while others deliberately try to individualize their MZ twins. As a result, researchers observe little systematic difference in the treatment of MZ and DZ twins by their parents. In fact, studies have shown that in cases where parents made incorrect conclusions about the zygosity of their twins, it was actual, rather than perceived, zygosity that predicted similarity between twins (Scarr and Carter-Saltzman, 1979). Given this evidence, Lykken *et al.*, (1993) argued that researchers can safely assume that pairs of MZ and DZ twins, on average, face the same environments, and heritability can be estimated conservatively from samples of twins reared together.

Sample

Our sample consists of 3,454 twins, comprising 870 pairs of MZ and 857 pairs of same sex DZ pairs from the TwinsUK registry—the national volunteer twin register in the U.K.—initially recruited through a national media campaign to collect data for medical research (www.twinsuk.ac.uk, Spector *et al.*, 1996). All were healthy volunteers with no cognitive or neuropsychological defects, and were comparable to age-matched singletons (Andrew *et al.*, 2001). The zygosity of the twins was determined by a standard validated questionnaire, which has an accuracy of more than 95 percent (Martin and Martin, 1975; Peeters *et al.*, 1998), and was validated where necessary through multiplex DNA fingerprinting using variable tandem repeats, which has a 99.7 percent accuracy (Singer *et al.*, 2005). Table 3 shows the descriptive statistics on the sample, as well as the correlation matrix, and provides information on such things as the gender and age of the respondents.

In 2006, each subject was sent a postal questionnaire that focused mainly on health-related issues and medical history. For example, it included questions on osteoporosis, response to pain, dyslexia, and exercise. Given the focus of the questionnaire, respondents were unaware of the hypotheses of this study when deciding whether or not to respond to the survey. Table 1 shows the questionnaire items used in this study.

Measures of entrepreneurship

The research literature does not agree on the definition of entrepreneurship. Given these differences, we seek convergent validity for our argument by examining several different operationalizations common in the literature. These include: (1)

starting a new business (Gartner, 1988; Mesch and Czamanski, 1997; Delmar and Davidsson, 2000), which we operationalize with the question ‘In your working life, how many new businesses have you started?’; (2) being an owner-operator of a company (Hull, Bosley, and Udell, 1980; Ahmed, 1985; Bitler *et al.*, 2005), which we operationalize with the question ‘In your working life, how many companies have you been an owner-operator of?’; (3) engaging in the firm start-up process (Reynolds *et al.*, 2004; Ruef, Aldrich, and Carter, 2003; Delmar and Shane, 2003), which we operationalize with the question ‘In your working life, for how many new business ideas have you taken any actions toward the creation of a new business?’; and (4) self-employment (Amit, Muller, and Cockburn, 1995; Evans and Leighton, 1989; Taylor, 1996; Le, 1999; Burke, FitzRoy, and Nolan, 2000; Van Praag and Cramer, 2001; Parker, 2004; Sorensen, forthcoming), which we operationalize with the question ‘In your working life, how long have you been self employed?’ The types of businesses that the entrepreneurs in our study have started are similar to those found in most studies of new business creation or self-employment conducted on representative samples of the population. That is, the distribution of new businesses in the sample resembles the distribution of new businesses started in the United Kingdom.

Sensation seeking

We used the sensation-seeking scale from the short form of the Zuckerman Kuhlman Personality Questionnaire (ZKPQ-S) (Zuckerman, 2002). The ZKPQ-S draws from earlier versions of the ZKPQ that have been developed and refined for over a decade (Zuckerman, Kuhlman, Thornquist, and Kiers,

Table 1. Questionnaire items

Variable	Item
Years self-employed	How long have you been self-employed?
Businesses owned and operated	How many companies have you been an owner-operator of?
Businesses founded	How many new businesses have you started?
Start-up efforts undertaken	For how many new business ideas have you taken any actions toward the creation of a new business?
Gender	(1 = female; 0 = male)
Age	Age of the respondents
Religious	(=atheist; 0 = religious)
Has children	(=children; 0 = no children)

Table 2. Sensation-seeking scale: Cronbach's $\alpha = 0.79$

Question	Loadings
I am an impulsive person.	0.79
I like 'wild' parties.	0.69
I enjoy getting into new situations where you can't predict how things will turn out.	0.78
I would like the kind of life where one is on the move and traveling a lot, with lots of changes and excitement.	0.72
I prefer friends who are excitingly unpredictable.	0.77
I often get so carried away by new and exciting things and ideas that I never think of possible complications.	0.81
I often do things on impulse.	0.84

1991; Zuckerman *et al.*, 1993; Zuckerman, 1994).⁵ The internal consistency and the convergent and discriminant validity of the questionnaire is well documented (Zuckerman, 2002; Angleitner, Riemann, and Spinath, 2004; Joireman and Kuhlman, 2004; Schmitz, 2004). Typical questions from the scale include 'I enjoy getting into situations where you can't predict how things will turn out;' 'I often get so carried away by new and exciting things and ideas that I never think of possible complications;' 'I am an impulsive person;' and 'I would like the kind of life where one is on the move and traveling a lot, with lots of changes and excitement.'

Factor analysis of the items composing the sensation-seeking scale (using tetrachoric correlations due to the dichotomous nature of the answer categories) revealed a single factor with an eigenvalue of 4.16. Table 2 shows the factor loadings of the items. A scale composed of the items had a reliability of 0.79.

Structural equation modeling

Following the standard approach in behavioral genetics, we use quantitative genetic modeling techniques (which are based on structural equation models fit to a dataset) to estimate the genetic and environmental contributions to twin resemblance in entrepreneurship (Neale and Cardon, 1992; Falconer, 1989; Sham *et al.*, 1994). Quantitative genetic theory holds that

three unobservable components can be combined additively to explain the variance in a phenotype (in our case, entrepreneurship) and generate the basic ACE model of behavioral genetics: genetic effects (A), shared environmental effects (or the environmental factors that people in the same family have in common) (C), and non-shared environmental effects (the environmental effects that are unique to an individual) (E).⁶ The models allow us to estimate the magnitude of the genetic and environmental influences as well as the confidence intervals of these estimates, and test the fit of the model (Plomin *et al.*, 1990).⁷

Figure 1 shows a graphical representation of the path models that we estimate. Observed entrepreneurship status is represented by the rectangles (Twin 1, Twin 2) while the latent factors, which the study estimates, are represented by the circles. A, C, and E correspond to the additive genetic, common environmental, and unique environmental influences, respectively. The curved, double-headed arrows between the latent variables represent the covariances between them. (Because monozygotic twins share the same genes and dizygotic twins share half their additive genes, the covariance between the latent additive genetic factors is 1.0 for MZs and 0.5 for DZs. Because monozygotic and dizygotic twins share the same common environment,

⁵Sensation seeking is one of the five factors that constitute the ZKPQ-S (the other four being neuroticism-anxiety; aggression-hostility; sociability; and activity). There are seven questions for each of these five factors in the ZKPQ-S (Zuckerman, 2002). We only used the seven questions from the sensation-seeking factor in the questionnaire that we administered to the twins.

⁶By environment, we mean all non-genetic effects (including the biological effects of the uterus, the home in which people are raised, and the social environment in which people live and work) on entrepreneurship. Thus, environmental effects are very much included in any quantitative genetics study, such as this one.

⁷McGue, Wette, and Rao (1987) showed that model fitting techniques provide parameter estimates that are robust to violations of normality assumptions.

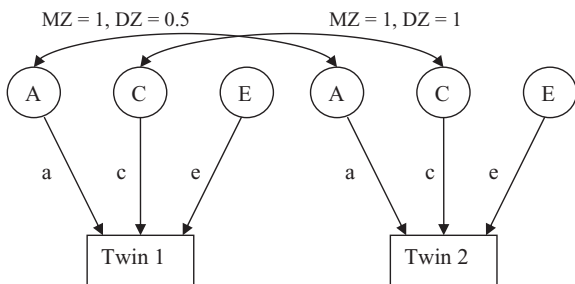


Figure 1. Path model for entrepreneurship status for Twin 1 And Twin 2

the covariance between the latent common environmental factors is 1.0 for both MZs and DZs.) The regression coefficients of the observed variables on the different latent factors are shown in lowercase letters: ‘a’ denotes the additive genetic effect, ‘c’ the common environmental effect, and ‘e’ the unique environmental effect.

The structural equations models that we use are represented by the following structural equations:

$$P_{ij} = aA_{ij} + cC_{ij} + eE_{ij}$$

$$V_p = a^2 + c^2 + e^2 = 1$$

where P is the phenotype of the i th individual in the j th pair ($i = 1,2; j = 1 \dots n$; all variables scaled as deviations from zero), and V_p is the total phenotypic variance of the population representing the sum of additive genetic variance (a^2), common environmental variance (c^2) and unique environmental variance (e^2).

These models generate the following predicted variance-covariance matrices for the ACE models:

		Twin 1	Twin 2
Cov MZ	Twin 1	=	$\begin{pmatrix} a^2 + c^2 + e^2 & a^2 + c^2 \\ a^2 + c^2 & a^2 + c^2 + e^2 \end{pmatrix}$
	Twin 2		
		Twin 1	Twin 2
Cov DZ	Twin 1	=	$\begin{pmatrix} a^2 + c^2 + e^2 & \frac{1}{2}a^2 + c^2 \\ \frac{1}{2}a^2 + c^2 & a^2 + c^2 + e^2 \end{pmatrix}$
	Twin 2		

We use maximum likelihood methods to produce parameter estimates of the variance in the genetic (A), shared environmental (C), and non-shared

environmental effects (E) (the coefficient for non-shared environmental effects includes measurement error). If entrepreneurship is entirely genetically determined, then the estimate of the contribution of genetic variance would be 1.00. In contrast, if entrepreneurship is entirely environmentally determined, then the estimate of the contribution of genetic variance would be 0.

The fit of the overall model is estimated using the chi-square goodness of fit test statistic, which is calculated by subtracting the log likelihood of the fitted model with the log likelihood of the observed data under a saturated model. A non-significant chi-square test shows that the model fits the data well (Betsworth *et al.*, 1994). (We also utilized the Akaike Information Criterion [AIC] [Akaike, 1987] and the Root Mean Square Error of Approximation [RMSEA] in the estimation of model fit and found similar results). The contribution of A, C, and E to the total variance is evaluated by removing each of them in a series of nested sub-model comparisons and testing the level of fit of each of the sub-models relative to the overall model.

To examine whether the heritability of entrepreneurship is genetically mediated through sensation seeking, we regressed out the effect of sensation seeking from each of the four measures of entrepreneurship and then computed heritability estimates on the adjusted results (Neale, 2004).

The ability to make strong causal statements about genetic factors also requires a correction for potential factors that can lead to a correlation of twin scores (Cropanzano and James, 1990). Therefore, we also adjusted the models for potential confounders associated with entrepreneurship (age, gender, religion, children) to see how estimates of the variance components varied once confounders were included in the models (Mohammed *et al.*, 2003; Hakim *et al.*, 2004).

RESULTS

The descriptive statistics and correlation matrices are shown in Table 3. The two groups of twins (MZ, DZ) were well matched for factors associated with entrepreneurship. There were no statistically significant differences between the two groups of twins on sensation seeking ($p = 0.33$) or our measures of entrepreneurship: self-employment ($p = 0.66$), owner-operator ($p = 0.99$), company founding

Table 3. Descriptive statistics and correlations

Variable	μ	σ	1	2	3	4	5	6	7	8
1. Age	55.60	13.20								
2. Gender	0.91	0.29	-0.01							
3. Religious	0.10	0.31	-0.08	-0.03						
4. Has children	0.73	0.44	0.30	0.02	-0.04					
5. Sensation seeking	0.28	0.28	-0.14	-0.05	0.02	-0.05				
6. Businesses founded	0.36	0.78	0.05	-0.09	0.06	0.05	0.44			
7. Businesses owned and operated	0.25	0.68	0.03	-0.09	0.04	0.04	0.47	0.64		
8. Years self-employed	0.68	1.33	0.09	-0.06	0.05	0.07	0.43	0.60	0.51	
9. Start-up efforts undertaken	0.48	0.96	0.02	-0.01	0.03	0.05	0.42	0.70	0.50	0.45

All correlations ≥ 0.05 significant at $p < 0.01$

Table 4. Heritabilities of the different measures of entrepreneurship

Dependent variable	A (95% CI)	C (95% CI)	E (95% CI)	χ^2 (d.f.)	RMSEA	AIC
Years self-employed	0.39 (0.24 to 0.44)	–	0.61 (0.56 to 0.66)	1.32 (4)	0.01	-6.68
Number of businesses owned and operated	0.37 (0.32 to 0.42)	–	0.63 (0.58 to 0.68)	1.12 (4)	0.01	-6.88
Number of businesses founded	0.42 (0.37 to 0.47)	–	0.58 (0.53 to 0.63)	7.29 (4)	0.03	-0.71
Number of start-up efforts	0.42 (0.37 to 0.47)	–	0.58 (0.53 to 0.63)	0.49 (4)	0.01	-7.51

A, additive genetic; C, common environment; E, unique environment. The table shows the results for the best-fitting model for each variable.

($p = 0.60$), or engaging in the business formation process ($p = 0.98$).

Table 4 shows the heritabilities of entrepreneurship across the four operationalizations of entrepreneurship. The chi-square test for goodness of fit for the model, the Akaike Information Criterion (Akaike, 1987), and the Root Mean Square Error of Approximation (RMSEA) showed that the best-fitting model to explain the variance in self-employment included additive genetic and environmental factors (AE) for all four operationalizations of entrepreneurship. (Table 4 reports the heritabilities of the best-fitting AE model only for each of the operationalizations of entrepreneurship.) Moreover, we found heritabilities that ranged between 0.37 and 0.42, leading us to conclude that there is convergent validity for the heritability of entrepreneurship.

We confirmed the findings of previous studies of the heritability of sensation seeking, which we estimate to be 0.32 in our sample. Given the phenotypic correlation between sensation seeking and entrepreneurship, we then estimated the genetic contribution to entrepreneurship that is mediated through genes affecting sensation-seeking behavior. After sensation seeking was included in the model, the contribution of genetic factors to entrepreneurship dropped

considerably (see Table 5). The analysis suggests that between 31 and 46 percent of the heritability of entrepreneurship was mediated by the psychological trait of sensation seeking.⁸

The results are robust on two key robustness checks. First, the results are qualitatively the same when we look at only the female respondents. This is important because measures of entrepreneurship are correlated with gender, leading estimates of genetic effects to be upwardly biased (all MZ twins share the same gender [McGue and Bouchard, 1984]). Second, the results do not change substantively when we adjust the model for potential confounders—age, gender, number of children, and religion—that have been shown to be associated with entrepreneurship (see Table 6; Aldrich and Kim, 2007; Shane, 2003).

DISCUSSION

We used quantitative genetics techniques to compare the entrepreneurial activity of a sample of MZ and

⁸We also calculated cross trait cross twin correlations (not reported here), which further corroborated our findings.

Table 5. Heritabilities of the different measures of entrepreneurship after taking out the effect of sensation seeking

Dependent variable	A (95% CI)	C (95% CI)	E (95% CI)	χ^2 (d.f.)	RMSEA	AIC
Years self-employed	0.25 (0.20 to 0.31)	–	0.75 (0.69 to 0.80)	2.27 (4)	0.01	–5.73
Number of businesses owned and operated	0.20 (0.14 to 0.25)	–	0.80 (0.75 to 0.86)	3.61 (4)	0.01	–4.39
Number of businesses founded	0.27 (0.21 to 0.32)	–	0.73 (0.68 to 0.79)	4.57 (4)	0.02	–3.43
Number of start-up efforts	0.29 (0.23 to 0.34)	–	0.71 (0.66 to 0.77)	5.93 (4)	0.02	–2.07

A, additive genetic; C, common environment; E, unique environment. The table shows the results for the best-fitting model for each variable.

Table 6. Heritabilities of the different measures of entrepreneurship after taking out the effect of sensation seeking (corrected for age, gender, religion, children)

Dependent Variable	A (95% CI)	C (95% CI)	E (95% CI)	χ^2 (d.f.)	RMSEA	AIC
Years self-employed	0.24 (0.17 to 0.30)	–	0.76 (0.70 to 0.83)	1.29 (4)	0.01	–6.71
Number of businesses owned and operated	0.17 (0.10 to 0.23)	–	0.83 (0.77 to 0.90)	6.48 (4)	0.03	–1.52
Number of businesses founded	0.27 (0.21 to 0.33)	–	0.73 (0.67 to 0.79)	7.07 (4)	0.03	–0.93
Number of start-up efforts	0.28 (0.22 to 0.34)	–	0.72 (0.66 to 0.78)	6.76 (4)	0.03	–1.24

A, additive genetic; C, common environment; E, unique environment. The table shows the results for the best fitting-model for each variable.

same-sex DZ twins from the United Kingdom. We ran model-fitting analyses to estimate the genetic, shared environmental, and non-shared environmental effects on the propensity of people to become entrepreneurs. We found, in the particular sample we examined, between 37 and 42 percent of the variance in the tendency of people to engage in entrepreneurship (heritability) is accounted for by genetic factors (through all the mechanisms through which genetic factors operate). Depending on the operationalization of the construct, between 31 and 46 percent of this variance was mediated by the psychological trait of sensation seeking, suggesting that genes affect the tendency of people to engage in entrepreneurship by affecting the distribution of sensation seeking across people.

Limitations

First, this study does not identify the genes that influence the tendency to engage in entrepreneurship. Therefore, we cannot know which genes matter, how many genes matter, or the relative importance of different genes to entrepreneurship. In fact, such information cannot be ascertained through twin studies

such as this one, but requires linkage or association studies to identify specific genes. Nevertheless, our results indicate the value of conducting molecular genetics studies of entrepreneurship because the results we have found suggest that researchers examine certain categories of genes.

Second, we have posited—but not directly tested—a mechanism through which genetic factors influence the tendency to become an entrepreneur. Our evidence suggests that genetic differences may affect brain physiology, leading some people to become high sensation seekers and others to become low sensation seekers. Because high sensation seekers have higher arousal thresholds, they are more willing to engage in careers that involve the bearing of risk in the pursuit of novelty, which entrepreneurship provides.

Third, like all quantitative genetics studies, this study assumes that there is no assortative mating. Assortative mating takes place when individuals tend to mate with individuals who have similar phenotypic characteristics. In evolution, assortative mating can decrease the range of variation in a trait, leading to overstated heritability estimates. Our study assumes that there is no assortative mating for entrepreneurship or sensation seeking. (We are

aware of no study that shows evidence of assortative mating for either characteristic.)

Fourth, our study cannot be directly generalized to males because the twin population we studied is overwhelmingly female. This gender imbalance exists for historical reasons (many of the initial medical conditions that the study was designed to address, such as osteoporosis, are more common among women than among men, leading to a focus on collecting data from women). While we have no reason to believe the results are gender specific (our analyses using females only and males and females yielded identical estimates of heritability), we cannot conclusively determine from our evidence that genetic factors influence the likelihood that men become entrepreneurs.

Implications

Our findings suggest the importance of considering the effects of genetic factors in explaining why people become entrepreneurs. Extant research does not explain all the variance in the tendency of people to become entrepreneurs, and examination of factors that account for some of this unexplained variance is important (Aldrich and Kim, 2007). The high heritabilities found for different operationalizations of entrepreneurship suggest that genetic factors may explain a significant portion of the unexplained variance in who becomes an entrepreneur. Moreover, because genetic factors are exogenous (genetic factors can affect entrepreneurship, but entrepreneurship cannot affect genetic factors), we can attribute causality to the correlations observed in this study. That is, genetic factors make some people more likely than others to become entrepreneurs.

The study shows evidence that genetic factors operate through a particular mechanism. They influence the distribution of sensation seeking across individuals. Sensation seeking increases the probability that people will become entrepreneurs, just as it affects the probability that they will engage in a variety of other activities that involve the bearing of risk in the pursuit of novelty. Given a random distribution of the necessary environmental stimulus across the population, the high sensation seekers are more likely than the low sensation seekers to start businesses, as we observe.

So what implications do our findings have? While we do not want to draw too strong conclusions from a single study and certainly do not want to make

recommendations for public policy or entrepreneurial practice until more work has been done, our results have several implications for the scholarly investigation of entrepreneurship. Our results offer the potential to reinvigorate a longstanding, but not universally agreed upon, aspect of entrepreneurship research: the role of individual differences in the tendency of people to become entrepreneurs. Although some entrepreneurship researchers consider individual differences to be an important explanatory factor in who becomes an entrepreneur (Shane and Venkataraman, 2000), many researchers believe individual differences are unimportant (Gartner and Carter, 2003), or even a dead end (Aldrich and Wiedenmeyer, 1993). As a result, in recent years, the field of entrepreneurship has tended to focus less on the role of individuals and more on the role of environmental conditions to explain the tendency of people to become entrepreneurs (Thornton and Flynn, 2003). Our results indicate that individual differences matter considerably because they are an important mechanism through which genes affect the tendency of people to become entrepreneurs.

Moreover, our results point to a key mechanism through which genetic factors lead some people to become entrepreneurs. Genes affect the likelihood that people will be high or low sensation seekers. High sensation seekers are more likely than low sensation seekers to become entrepreneurs because entrepreneurship offers a career in which people can bear risk in the pursuit of novelty, which is attractive to high sensation seekers. This pattern suggests that future researchers might further investigate the effect of this individual difference on the tendency of people to engage in entrepreneurship, as this dimension has received relatively little scholarly examination.

Furthermore, our findings suggest that the genes associated with sensation seeking are plausible candidate genes for molecular studies of entrepreneurial activity. Since researchers have already found an association between the 7-repeat allele of the DRD4 gene and sensation seeking (Ebstein *et al.*, 1996; Benjamin *et al.*, 1996), our finding of genetic mediation by sensation seeking in the heritability of entrepreneurship suggests that this variant of the DRD4 gene is also a good candidate for investigation by molecular geneticists interested in finding genes associated with entrepreneurial activity.

Finally, our findings bound the very concept on which this new journal is based. Our results are consistent with the argument that some people are more

likely to become entrepreneurs than others because genetic factors lead them to produce an enzyme that affects their likelihood of becoming sensation seeking, and high sensation seekers are more likely than low sensation seekers to pursue careers, like entrepreneurship, that involve the bearing of risk in the pursuit of novelty. Therefore, at least some of the variance in the decision to become an entrepreneur involves physiological processes that people are not conscious of, making the decision of people to become entrepreneurs less a function of strategic choice than is commonly believed.

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REFERENCES

- Ahmed S. 1985. nAch, risk taking, locus of control, and entrepreneurship. *Personality and Individual Differences* **6**(6): 781–782.
- Akaike H. 1987. Factor analysis and AIC. *Psychometrika* **52**: 317–332.
- Aldrich HE, Martinez MA. 2001. Many are called but few are chosen: An evolutionary perspective for the study of entrepreneurship. *Entrepreneurship Theory & Practice* **25**(Summer): 41–56.
- Aldrich HE, Kim P. 2007. A life course perspective on occupational inheritance: self-employed parents and their children. In *Research in the Sociology of Organizations*, Ruef M, Lounsbury M (eds). Elsevier: Amsterdam; 33–82.
- Aldrich HE, Wiedenmayer G. 1993. From traits to rates: an ecological perspective on organizational foundings. In *Advances in Entrepreneurship, Firm Emergence, and Growth*, Katz J, Brockhaus R (eds). JAI Press: Greenwich, CT; 145–195.
- Amit R, Muller E Cockburn I. 1995. Opportunity costs and entrepreneurial activity. *Journal of Business Venturing* **10**(2): 95–106.
- Andrew T, Hart DJ, Sneider H, de Lange M, Spector TD, MacGregor AJ. 2001. Are twins and singletons comparable? A study of disease-related and lifestyle and lifestyle characteristics in adult women. *Twin Research* **4**: 464–77.
- Angleitner A, Riemann R, Spinath FM. 2004. Investigating the ZKPKQ-III-R: psychometric properties, relations to the five-factor model, and genetic and environmental influences to its scales and facets. In *On the Psychobiology of Personality: Essays in Honor of Marvin Zuckerman*, Stelmack RM (ed). Elsevier: Oxford, U.K.; 89–105.
- Arnett J. 1990. Drunk driving, sensation seeking, and egocentrism among adolescents. *Personality and Individual Differences* **11**(6): 541–546.
- Baron R. 2002. OB and entrepreneurship: The reciprocal benefits of closer conceptual links. In *Research in Organizational Behavior*, Staw B, Kramer E (eds). Greenwich, CT: JAI Press, 225–269.
- Baron RA. 2004. The cognitive perspective: A valuable tool for answering entrepreneurship's basic 'why' questions. *Journal of Business Venturing* **19**(2): 221–239.
- Baum JR, Frese M, Baron RA. 2007. *The Psychology of Entrepreneurship*. Lawrence Erlbaum Associates.
- Begley T, Boyd D. 1986. Psychological characteristics associated with entrepreneurial performance. In *Frontiers of Entrepreneurship Research*, Ronstadt R, Hornaday J, Peterson R, Vesper K (eds). Babson College, Babson Park, MA; 146–165.
- Begley T, Boyd D. 1987. A comparison of entrepreneurs and managers of small business firms. *Journal of Management* **13**: 99–108.
- Benjamin J, Ebstein RP, Belmaker RH. 2003. Genes for human personality traits: endophenotypes of psychiatric disorders? In *Molecular Genetics and the Human Personality*, Benjamin J, Ebstein RP, Belmaker RH (eds). APA: Washington, D.C.; 333–343.
- Benjamin J, Li L, Patterson C, Greenburg BD, Murphy DL, Hamer DH. 1996. Population and familial association between the D4 dopamine receptor gene and measures of novelty seeking. *Nature Genetics* **12**: 81–84.
- Betsworth D, Bouchard T, Cooper C, Grotevant H, Hansen J, Scarr S, Weinberg R. 1994. Genetic and environmental influences on vocational interests assessed using adoptive and biological families and twins reared together and apart. *Journal of Vocational Behavior* **44**: 263–278.
- Bird B. 1989. *Entrepreneurial Behavior*. Glenview, IL: Scott, Foresman and Company.
- Bitler MP, Moskowitz T, Vissing-Jørgensen A. 2005. Testing agency theory with entrepreneur effort and wealth. *Journal of Finance* **60**(2): 539–576.
- Bouchard TJ. 1998. Genetic and environmental influences on intelligence and special mental abilities. *Human Biology* **70**(2): 257–259.
- Bouchard TJ, Lykken D, McGue N, Segal N, Tellegen A. 1990. Sources of human psychological difference: the Minnesota study of twins reared apart. *Science* **12**(Oct.): 223–228.
- Bouchard TJ, Propping P. 1993. *Twins as a tool of behavioral genetics*. John Wiley & Sons: Chichester, U.K.
- Bouchard TJ, Segal NL, Tellegen A, McGue M, Keyes M, Krueger R. 2004. Genetic influence on social attitudes: Another challenge to psychology from behavioural genetics. In *Behavior Genetics Principles: Perspectives*

- in *Development, Personality, and Psychopathology*, DiLalla LF (ed). APA: Washington, D.C.
- Burke AE, FitzRoy FR, Nolan MA. 2000. When less is more: distinguishing between entrepreneurial choice and performance. *Oxford Bulletin of Economics and Statistics* **62**: 567–587.
- Busenitz L. 1999. Entrepreneurial risk and strategic decision making. *Journal of Applied Behavioral Science* **35**(3): 325–340.
- Carey G. 2003. *Human Genetics for the Social Sciences*. Sage: Thousand Oaks, CA.
- Cloninger C, Adolfsson R, Svrakic N. 1996. Mapping genes for human personality. *Nature Genetics* **12**: 3–4.
- Collins CJ, Hanges P, Locke EA. 2004. The relationship of need for achievement to entrepreneurship: A meta-analysis. *Human Performance* **17**: 95–117.
- Cooper A, Woo C, Dunkelberg W. 1988. Entrepreneurs' perceived chances for success. *Journal of Business Venturing* **3**(2): 97–108.
- Cromie S, Johns S. 1983. Irish entrepreneurs: some personal characteristics. *Journal of Organizational Behavior* **4**: 317–324.
- Cropanzano R, James K. 1990. Some methodological considerations for the behavioral genetic analysis of work attitudes. *Journal of Applied Psychology* **75**(4): 433–429.
- Delmar F, Davidsson P. 2000. Where do they come from? Prevalence and characteristics of nascent entrepreneurs. *Entrepreneurship and Regional Development* **12**: 1–23.
- Delmar F, Shane S. 2003. Does business planning facilitate the development of new ventures? *Strategic Management Journal* **24**(12): 1165–1185.
- DiLalla L. 2004. Behavioral genetics: background, current research, and goals for the future. In *Behavior Genetics Principles: Perspectives in Development, Personality, and Psychopathology*, DiLalla L (ed). APA: Washington, D.C.
- Ebstein RP, Novick O, Umansky R, Priel B, Osher Y, Blaine D. 1996. Dopamine D₄ receptor (D₄DR) exon III polymorphism associated with the human personality trait novelty seeking. *Nature Genetics* **12**(1): 78–80.
- Evans D, Leighton L. 1989. Some empirical aspects of entrepreneurship. *American Economic Review* **79**: 519–535.
- Falconer D. 1989. *Introduction to Quantitative Genetics*, Harlow, Essex, U.K.: Longman.
- Fulker DW, Eysenck SGB, Zuckerman M. 1980. The genetics of sensation seeking. *Journal of Personality Research* **14**: 261–281.
- Gartner W. 1988. Who is an entrepreneur? Is the wrong question. *American Journal of Small Business* **12**(4): 11–32.
- Gartner W, Carter N. 2003. Entrepreneurial behaviour and firm organizing process. In *Handbook of Entrepreneurship Research*, Acs Z, Audretsch D (eds). Kluwer: Boston, MA; 195–222.
- Geen R. 1997. Psychophysiological approaches to personality. In *Handbook of Personality Psychology*, Hogan R, Johnson J, Briggs S (eds). Academic Press: New York; 387–414.
- Grigorenko E. 2003. Epistasis and the genetics of complex traits. In *Behavioral Genetics in the Postgenomic Era*, Plomin R, DeFries JC, Craig IW, McGuffin P. American Psychological Association: Washington, D.C.; 247–266.
- Hakim AJ, Cherkas LF, Grahame R, Spector TD, MacGregor AJ. 2004. The genetic epidemiology of joint hypermobility: a population study of female twins. *Arthritis and Rheumatism* **50**(8): 2640–2644.
- Hettema JM, Neale MC, Kendler KS. 1995. Physical similarity and the equal environment assumption in twin studies of psychiatric disorders. *Behavior Genetics* **25**: 327–335.
- Hull D, Bosley J, Udell G. 1980. Renewing the hunt for the heffalump: identifying potential entrepreneurs by personality characteristics. *Journal of Small Business Management* **18**(1): 11–18.
- Hur Y, Bouchard T. 1997. The genetic correlation between impulsivity and sensation-seeking traits. *Behavior Genetics* **27**(5): 455–463.
- Jack SJ, Ronan KR. 1998. Sensation seeking among high- and low-risk sports participants. *Personality and Individual Differences* **25**: 1063–1083.
- Joireman J, Anderson J, Strathman A. 2003. The aggression paradox: understanding links among aggression, sensation seeking, and the consideration of future consequences. *Journal of Personality and Social Psychology* **84**(6): 1287–1302.
- Joireman J, Kuhlman DM. 2004. The Zuckerman-Kuhlman Personality Questionnaire: Origin, development, and validity of a measure to assess an alternative five-factor model of personality. In *On the Psychobiology of Personality: Essays in honor of Marvin Zuckerman*, Stelmack RM (ed). Elsevier: Oxford, U.K.; 49–63.
- Joy S. 2004. Innovation motivation: the need to be different. *Creativity Research Journal* **16**(2/3): 313–330.
- Kendler KS, Neale MC, Kessler RC, Heath AC, Eaves LJ. 1993. A test of the equal environment assumption in twin studies of psychiatric illness. *Behavior Genetics* **23**: 21–27.
- Khilstrom R, Laffont J. 1979. A general equilibrium entrepreneurial theory of firm formation based on risk aversion. *Journal of Political Economy* **87**(4): 719–748.
- Knight F. 1921. *Risk, Uncertainty, and Profit*. Augustus Kelly: New York.
- Koopmans J, Boomsma D, Heath A, Van Doornen L. 1995. A multivariate genetic analysis of sensation seeking. *Behavior Genetics* **25**: 349–356.
- Le AT. 1999. Empirical studies of self-employment. *Journal of Economic Surveys* **13**(4): 381–416.
- Linnet J, Rojskjaer S, Nygaard J, Maher B. 2006. Episodic chasing in pathological gamblers using the Iowa

- gambling task. *Scandinavian Journal of Psychology* **47**: 43–49.
- Lusher J, Ebersole L, Ball D. 2000. Dopamine D4 receptor gene and severity of dependence. *Addiction Biology* **5**: 469–472.
- Lykken D, Bouchard T, McGue M, Tellegen A. 1993. Heritability of interests: a twin study. *Journal of Applied Psychology* **78**(4): 649–661.
- Martin NG, Martin PG. 1975. The inheritance of scholastic abilities in a sample of twins: ascertainment of the sample and diagnosis of zygosity. *Annals of Human Genetics* **39**: 213–218.
- McClelland D. 1961. *The Achieving Society*. Van Nostrand: Princeton, NJ.
- McGue M, Bouchard TJ. 1984. Adjustment of twin data for the effects of age and sex. *Behavioral Genetics* **14**: 325–343.
- McGue M, Wette R, Rao D. 1987. A Monte Carlo evaluation of three statistical methods used in path analysis. *Genetic Epidemiology* **429**: 129–155.
- Mesch GS, Czamanski D. 1997. Occupational closure and immigrant entrepreneurship: Russian Jews in Israel. *Journal of Socio-Economics* **26**(6): 597–610.
- Mohammed I, Cherkas LF, Riley SA, Spector TD, Trudgill NJ. 2003. Genetic influences in gastro-oesophageal reflux disease: a twin study. *Gut* **52**: 1085–1089.
- Neale MC. 2004. Twin analysis. In *Encyclopaedia of Biostatistics* (6th edn), Armitrage P, Colton T (eds). John Wiley & Sons: London.
- Neale MC, Cardon L. 1992. *Methodology for Genetic Studies of Twins and Families*. Kluwer Academic Publishers: Dordrecht, The Netherlands.
- Noble EP, Ozkaragoz TZ, Ritchie TL, Zhang X, Belin TR, Sparkes RS. 1998. D2 and D4 dopamine receptor polymorphisms and personality. *American Journal of Medical Genetics* **81**(3): 257–67.
- Parker SC. 2004. *The economics of self-employment and entrepreneurship*. Cambridge University Press: Cambridge, U.K.
- Peeters H, Gestel S, Vlietinck R, Derom C, Derom R. 1998. Validation of a telephone zygosity questionnaire in twins of known zygosity. *Behavior Genetics* **28**(3): 159–163.
- Plomin R, Daniels D. 1987. Why are children in the same family so different from one another? *Behavioral and Brain Sciences* **10**(1): 1–16.
- Plomin R, DeFries J, McClearn G. 1990. *Behavioral Genetics: A Primer* (2nd edn). Freeman: New York.
- Plomin R, DeFries JC, McClearn GE, McGuffin P. 2001. *Behavioral Genetics* (4th edn). Worth Publishers: New York.
- Plomin R, Lichtenstein P, Pedersen NL, McClearn GE, Nesselroade JR. 1990. Genetic influence on life events during the last half of the life span. *Psychology and Aging* **5**: 25–30.
- Plomin R, Walker SO. 2003. Genetics and educational psychology. *British Journal of Educational Psychology* **73**: 3–14.
- Rauch A, Frese M. 2000. Psychological Approaches to Entrepreneurial Success: A General Model and an Overview of Findings. In *International Review of Industrial and Organizational Psychology* 15, Cooper CL, Robertson LT (eds). Chichester, U.K.: Wiley.
- Reynolds P, Carter N, Gartner W, Greene P. 2004. The prevalence of nascent entrepreneurs in the United States: evidence from the panel study of entrepreneurial dynamics. *Small Business Economics* **23**: 263–284.
- Rosenbloom T. 2003. Risk evaluation and risky behavior of high and low sensation seekers. *Social Behavior and Personality* **31**(4): 375–386.
- Ruef M, Aldrich H, Carter N. 2003. The structure of founding teams: homophily, strong ties, and isolation among U.S. entrepreneurs. *American Sociological Review* **68**: 195–222.
- Scarr S, Carter-Saltzman L. 1979. Twin method: defense of a critical assumption. *Behavior Genetics* **9**: 527–542.
- Schmitz PG. 2004. On the alternative five-factor model: structure and correlates. In *On the Psychobiology of Personality: Essays in Honor of Marvin Zuckerman*, Stelmack RM (ed). Elsevier: Oxford, U.K.
- Sham PC, Walters EE, Neale MC, Heath AC, MacLean CJ, Kendler KS. 1994. Logistic regression analysis of twin data: estimation of parameters of the multifactorial liability-threshold model. *Behavior Genetics* **24**: 229–238.
- Shane S. 2003. *A General Theory of Entrepreneurship: The Individual-Opportunity Nexus*. Edward Elgar Publishing: Aldershot, U.K.
- Shane S, Khurana R. 2003. Bringing individuals back in: the effects of career experience on new firm founding. *Industrial and Corporate Change* **12**(3): 519–543.
- Shane S, Venkataraman S. 2000. The promise of entrepreneurship as a field of research. *Academy of Management Review* **25**: 217–226.
- Singer JJ, MacGregor AJ, Cherkas LF, Spector TD. 2005. Where did I leave my keys? A twin study of self-reported memory ratings using the multifactorial memory questionnaire. *Twin Research and Human Genetics* **8**(2): 108–112.
- Sjoberg L, Engelberg E. 2006. Attitudes to economic risk taking, sensation seeking, and values of business students specializing in finance. *SSE/EFI Working Paper Series in Business Administration* **3**.
- Sorenson J. 2007. Closure versus exposure: Mechanisms in the intergenerational transition of self-employment. In *Research in the Sociology of Organizations*, Ruef M, Lounsbury M (eds). Elsevier: Amsterdam; 83–124.
- Spector T, Cicuttini F, Baker J, Loughlin J, Hart D. 1996. Genetic influences on osteoarthritis in women: a twin study. *BMJ* **312**: 940–944.
- Stephenson M, Hoyle R, Palmgreen P, Slater M. 2003. Brief measures of sensation seeking for screening and

- large-scale surveys. *Drug and Alcohol Dependence* **72**: 279–286.
- Stewart WH, Roth PL. 2001. Risk-taking propensity differences between entrepreneurs and managers: a meta-analytic review. *Journal of Applied Psychology* **86**(1): 145–153.
- Stewart WH, Roth PL. 2004. Data quality affects meta-analytic conclusions: a response to Miner and Raju (2004) concerning entrepreneurial risk propensity. *Journal of Applied Psychology* **89**: 14–21.
- Taylor M. 1996. Earnings, independence, or unemployment: why become self-employed? *Oxford Bulletin of Economics and Statistics* **58**: 253–266.
- Thornton P, Flynn K. 2003. Entrepreneurship, networks, and geographies. In *Handbook of Entrepreneurship Research*, Acs Z, Audretsch D (eds). Kluwer Academic Publishing: Boston, MA; 401–436.
- Van Praag C, Cramer J. 2001. The roots of entrepreneurship and labour demand: individual ability and low aversion. *Economica* **68**(269): 45–62.
- Van Tol H, Bunzow J, Guan H, Sunahara R, Seeman P, Niznik H, Civelli O. 1991. Cloning of the gene for a human dopamine D4 receptor with high affinity for the antipsychotic clozapine. *Nature* **350**(6319): 610–614.
- Van Tol H, Wu C, Guan H, Ohara K, Bunzow J, Civelli O, Kennedy J, Seeman P, Niznik H, Jovanovic V. 1992. Multiple dopamine D4 receptor variants in the human population. *Nature* **358**(6382): 149–152.
- Weber E, Blais A, Betz N. 2002. A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making* **15**: 263–290.
- White R, Thornhill S, Hampson E. 2006. Entrepreneurs and evolutionary biology: the relationship between testosterone and new venture creation. *Organizational Behavior and Human Decision Processes* **100**: 21–34.
- White R, Thornhill S, Hampson E. 2007. A biosocial model of entrepreneurship: the combined effects of nurture and nature. *Journal of Organizational Behavior* **28**(4): 451–466.
- Wolf JB, Brodie ED III, Wade MJ. 2000. *Epistasis and the evolutionary process*. New York: Oxford University Press.
- Wong A, Carducci B. 1991. Sensation seeking and financial risk taking in everyday money matters. *Journal of Business and Psychology* **5**: 525–530.
- Zuckerman M. 1983. Sensation seeking and sports. *Personality and individual differences* **4**: 285–292.
- Zuckerman M. 1994. *Behavioral Expressions and Biosocial Bases of Sensation Seeking*. Cambridge University Press: Cambridge, U.K.
- Zuckerman M. 2002. Zuckerman-Kuhlman Personality Questionnaire (ZKPQ): an alternative five-factorial model. In *Big Five Assessment*, DeRaad B, Perugini M (eds). Hogrefe and Huber: Cambridge, MA; 377–396.
- Zuckerman M. 2004. The shaping of personality: genes, environments, and chance encounters. *Journal of Personality Assessment* **82**(1): 11–22.
- Zuckerman M, Eysenck S, Eysenck HJ. 1978. Sensation seeking in England and America: cross-cultural, age, and sex comparisons. *Journal of Consulting and Clinical Psychology* **46**: 139–149.
- Zuckerman M, Kuhlman DM, Thornquist M, Kiers H. 1991. Five (or three) robust questionnaire scale factors of personality without culture. *Personality and Individual Differences* **12**(9): 929–941.
- Zuckerman M, Kuhlman DM, Joireman J, Teta P, Kraft M. 1993. A comparison of three structural models for personality: the big three, the big five and the alternative five. *Journal of Personality and Social Psychology* **65**(4): 757–768.