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Can genetic factors influence the likelihood of engaging in entrepreneurial activity?

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Abstract

This article offers an argument for how genetic factors may influence the tendency of people to engage in entrepreneurial activity, and describes four mechanisms through which genetic factors could operate. It also explores ways that researchers can use quantitative and molecular genetics to examine entrepreneurship, and discusses the potential implications of a genetic perspective for management research on entrepreneurship.

Keywords: Behavioral genetics; Entrepreneurship

1. Executive summary

Entrepreneurship scholars have identified a variety of factors that affect the tendency of people to engage in entrepreneurial activity (Shane, 2003). However, one of the most interesting factors – genetics – has not been examined. In this paper, we provide an argument for how genetic factors might influence the *likelihood* that some individuals pursue entrepreneurial activity. Drawing from the behavioral genetics literature, we propose that genetic factors *may* influence the tendency of people to engage in entrepreneurial activity in four complementary ways. First, genes may affect chemical mechanisms in the brain to increase the likelihood that people will engage in entrepreneurial activity. Second, genes might predispose people to develop individual attributes, such as extraversion and internal locus of control, that affect the tendency of people to engage in entrepreneurial activity. Third, genes may make some people more sensitive than others to environmental stimuli that increase the likelihood of engaging in entrepreneurial activity. Fourth, genes may influence exposure to environments that are more favorable to entrepreneurship.

We also discuss different ways through which the contribution of genetic factors to the tendency of people to engage in entrepreneurial activity may be assessed. The first approach, known as *quantitative genetics*, estimates genetic and

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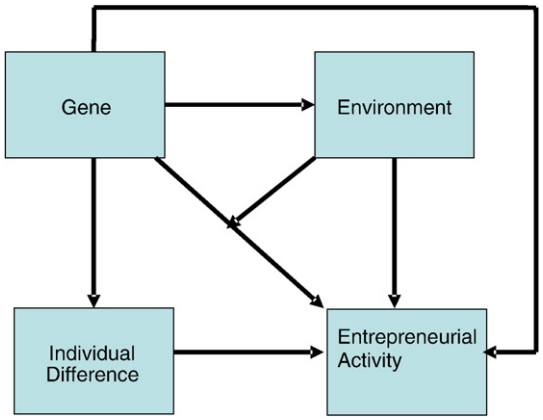

Fig. 1. Mechanisms through which genetic factors influence entrepreneurship.

environmental contributions to phenotypic variance in a population from patterns of genetic relationships among individuals, and usually involves the use of twin and adoption studies (Plomin et al., 2001a,b). The second approach, known as *molecular genetics*, identifies specific genes that contribute to variation between individuals in some social outcome (Ebstein et al., 1996).

Finally, we discuss how research on genetic factors could inform entrepreneurship research. Examples of potential contributions include: informing research on the objectivity or subjectivity of entrepreneurial opportunities, identifying the mechanism through which parental self-employment influences children's propensity to become self-employed (Aldrich and Kim, 2007), and evaluating the validity of the individual differences literature in entrepreneurship (Baron, 2004; White, Thornhill and Hampson, 2006).

2. Introduction

For forty years researchers have examined who becomes an entrepreneur (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 which members of society engage in entrepreneurial activity and which do not (see Shane, 2003, chapters 4 and 5 for a review), one of the most interesting explanations for the tendency of people to engage in entrepreneurial activity – 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 of who becomes an entrepreneur. Specifically, the article provides a process theoretic explanation for how genes may influence the tendency of people to engage in entrepreneurial activity.

We define a gene as a piece of DNA that is passed from parents to their biological children during reproduction and which influences an observed characteristic of an individual, referred to as a phenotype. Thus, the "genetic factors" that we discuss in this paper are those factors that influence the tendency of people to engage in entrepreneurial activity, which are encoded in DNA and transmitted biologically, as opposed to those factors that influence the tendency of people to engage in entrepreneurially activity, which are not encoded in DNA and are not transmitted biologically.

We propose that genetic factors may influence the tendency of people to engage in entrepreneurial activity in four complementary ways (see Fig. 1). First, genes may affect chemical mechanisms in the brain to increase the likelihood that people will engage in entrepreneurial activity. Second, genes may influence individual differences,[2] such as extraversion and internal locus of control, that predispose people to engage in entrepreneurial activity. Third, genes may make some people more sensitive than others to environmental stimuli that increase the likelihood of engaging in entrepreneurial activity. Fourth, genes may affect the tendency of people to select into environments that are more favorable to entrepreneurship.

[2] We use the term "individual differences" to refer to enduring psychological attributes of people in a way consistent with past research on entrepreneurship. This mechanism differs from the first mechanism even though the first mechanism clearly involves differences between individuals because the second mechanism operates through enduring psychological attributes of people and the first does not.

We also discuss how researchers can use quantitative and molecular genetics, two approaches important to understanding the effect of genetics on human behavior, to explain people's tendency to engage in entrepreneurial activity.[3] In particular, the paper discusses how researchers can separate genetic from environmental influences, given the potential for gene–environment interactions and gene–environment correlations.

Finding evidence of genetic influences in entrepreneurship will not be easy. It will require hard-to-collect samples and inter-disciplinary collaborations. Moreover, it will require the field of to grapple with its lack of consensus on the definition of "entrepreneurship" and with variation in the effects of genetic factors over time. Any findings that are seen in empirical work might not survive the test of replication. And the investigation of genetic influences in entrepreneurship may provide only minor insights into the phenomenon. Our aim, therefore, is not to be prescriptive. Rather, we hope that by pointing out why researchers might want to look at the effect of genetic factors and how they might go about doing that, we might start off a new conversation in the field.

We begin that conversation by suggesting why it might be important to examine the process through which genetic factors influence who engages in entrepreneurial activity. First, examining the role of genetic factors might lead to the development of new theories, raise questions about old ones, and open up paths of inquiry heretofore not considered. For example, in recent years management researchers have tended to emphasize the role of situational factors rather than individual differences in explaining people's propensity to engage in entrepreneurial activity (Thornton and Flynn, 2003; Aldrich and Wiedenmayer, 1993; Gartner, 1988). While this focus has provided important insights into our understanding of who engages in entrepreneurial activity, some scholars (e.g., Stewart and Roth, 2001; Baron, 2002; Shane and Khurana, 2003; White, Thornhill and Hampson, 2006) have argued that researchers have overemphasized environmental factors at the expense of individual differences. Research on genetic factors might help to test whether there is an imbalance in attention given to situational factors, for example, by examining how genetic factors might affect the probability of developing individual differences that increase the tendency to engage in entrepreneurial activity, as well as to select into environments conducive to entrepreneurship.

An understanding of the role of genetic factors might also provide richer, more precise explanations for the tendency of people to engage in entrepreneurial activity. For example, genetic research could determine whether the influence of parental self-employment on children's propensity to become self-employed (Fairlie, 1999; Burke et al., 2000; Aldrich and Kim, 2007; Sorenson, 2007) is solely the result of information about how to run a business that is provided during childhood (the prevailing explanation in the literature) or whether it is also the result of genetic factors (an explanation not currently offered in the literature).

Second, an understanding of the role of genetic factors in entrepreneurship may help researchers to conduct better empirical entrepreneurship research. For example, an understanding of how genetic factors influence the tendency of people to engage in entrepreneurial activity would provide researchers with a mechanism to select the appropriate comparison group to test the effect of environmental conditions on that tendency. This would permit more precise tests of the effect of environmental factors, and, possibly, reveal patterns that have not been shown empirically, but have been posited theoretically. Similarly, an understanding of the role of genetic factors might indicate that evidence of an association between individual characteristics and the tendency of people to engage in entrepreneurial activity are artifacts of omitted variable bias because both individual characteristics and entrepreneurial activity are endogenously affected by genetic factors.

The paper proceeds as follows. The next section outlines the boundaries of our theory, making clear what we do and do not argue. The second section offers our process theory for how genetic factors might influence the tendency of people to engage in entrepreneurial activity and develops specific testable propositions about those mechanisms. The third section offers suggestions for how researchers might examine the influence of genes on the tendency of people to

[3] We believe that a discussion of methodological approaches to examining how genetic factors influence the tendency of people to engage in entrepreneurship is important to our effort to introduce genetics into the entrepreneurship literature. We are proposing that genetic factors play *some* role in entrepreneurship. Illustrating how one can methodologically investigate the influence of genetics factors on entrepreneurship helps us to accomplish this goal because an understanding of the role of genetic factors requires an understanding of what molecular and quantitative genetics studies can help to explain. Moreover, from a practical point of view, we believe that including both the process theory and information on how to test it makes the paper more useful to scholars in the field. To the best of our knowledge, ours is the first paper that attempts to bridge the disciplinary boundary between behavioral genetics and entrepreneurship. As a result most entrepreneurship/management scholars would be unfamiliar with genetics. Therefore, we believe that by briefly illustrating how scholars can conduct this research makes our ideas easier to comprehend.

engage entrepreneurial activity. The fourth section discusses implications for entrepreneurship research. The fifth section concludes.

3. The boundaries of our theory

We begin by highlighting the boundaries of our investigation. First, we are proposing that it is very unlikely that entrepreneurship is determined *solely* by environmental factors. That is, we are suggesting that genetic factors might also influence the propensity of people to engage in entrepreneurship.

It is important to make clear at the outset that we are only proposing that genes *might* matter. We are *not proposing* that genes *determine* who engages in entrepreneurial activity. Genetic factors do not *cause* people to engage in social activities, like entrepreneurship.[4] Genes only affect the probability that people will engage in those activities (Plomin et al., 1990). As Plomin et al. (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". Thus, our suggestion that genetic factors influence the tendency of people to engage in entrepreneurship should *not* be confounded with biological determinism (Turkheimer, 1998). As Alford et al. (2005: 163) explain, "it is not biological determinism to posit the existence of complex collections of genes that increase the probability that certain people will display heightened or deadened response patterns to given environmental cues" (Alford et al., 2005: 163).

Second, we are *not* suggesting that there is a specific gene for entrepreneurship. Entrepreneurship is a complex phenotype, and it is very unlikely that there is a strong association between having a certain allele of[5] a particular gene and the tendency to engage in entrepreneurship. 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. When it is very difficult to "trace in a clear and unambiguous fashion a complete set of causal links from DNA base-pair variation to a complex biobehavioral phenomenon" (Kendler, 2005a:8), then the relationship between genes and the phenotype (entrepreneurship) is very likely to violate the criterion of causal proximity (Kendler, 2005b) that is necessary for the simple 'X is a gene for Y' statement.

Third, we suggest that the effect of genetic factors on the tendency to engage in entrepreneurship could be both pleiotropic and polygenic. Pleiotropic effects mean that a gene that influences one social behavior also influences another (Plomin et al., 2001a,b). The pleiotropic effects of genes are important to explaining the role of genetic factors in the tendency of people to engage in entrepreneurship because a gene that increases the *propensity* of people to engage in entrepreneurship might also increase the propensity of people to engage in other activities, such as management.

Polygenic effects mean that two or more genes are needed to increase the *likelihood* that a particular social outcome will occur. Unlike specific medical disorders, like Huntington's disease, in which a single gene is responsible for the disorder, there are no known one-to-one relationships between specific genes and human behaviors. Therefore, a number of genes may be needed in order to increase the *likelihood* that a person will engage in entrepreneurship. These genetic influences might be additive or they might be epistatic[6] (either way, the independent main effects of any one gene on entrepreneurship are probably negligible).

Fourth, we note that our proposed explanation for the role of genetic factors is *complementary* to environmentally-driven explanations. It does *not* reject the possibility that other factors, such as the exogenously determined external environment, also influence the tendency of people to engage in this activity. Moreover, our proposed explanation is explicitly *interactionist* — it advocates transactions between genetic and environmental influences. We suggest that genetic factors may, and probably do, *interact* with environmental factors to account for the tendency of people to engage in entrepreneurship, and we specifically identify gene–environment interactions as a mechanism through which genetic factors may influence this tendency.

[4] In genetics, the probability that a person exhibits a phenotype given that the person has the genotype for that phenotype is known as *penetrance*. Thus, *complete penetrance* refers to the situation where the probability of developing a phenotype is 1, meaning that if the person has the genotype he/she will definitely develop the disorder or trait (e.g. Huntington's disease). The tendency to engage in entrepreneurial activity is a case of *incomplete penetrance* where this probability is significantly below 1.0.

[5] An allele is any one of a number of possible DNA codings of the same gene.

[6] Epistasis refers to the interaction between genes (Wolf et al., 2000; Grigorenko, 2003).

Due to the relative infancy of the fields of behavioral genetics and entrepreneurship, and the breadth of both areas, we restrict our discussion of the possible effect of genetic factors to the single issue of who engages in entrepreneurship, and leave the discussion of how genetic factors might influence other aspects of the entrepreneurial process and the performance of entrepreneurs to future research.[7] The complexity of explaining the effect of genetic factors on all aspects of the entrepreneurial process simultaneously with almost no empirical evidence on this question makes any more specific investigation so speculative as to be unscholarly.[8]

We propose that the *mechanisms* through which genetic factors influence the tendency of people to engage in entrepreneurship are the same regardless of the operationalization of entrepreneurship (i.e. whether it is recognizing and exploiting opportunities; self-employment; firm formation, etc…). Therefore, we do not offer any arguments that are conditional on entrepreneurial activity taking one of these particular forms.

A lack of convergent validity between empirical tests examining the effect of genetic factors on the different operationalizations of entrepreneurship would not falsify our theoretical arguments, but, instead, would reflect the problems that exist with current operationalizations of the construct employed by the field of entrepreneurship. Researchers could fail to find results for certain operationalizations of entrepreneurship (e.g., self-employment; firm formation; being an owner–operator) because the variance in the ways in which entrepreneurship has been defined is too large for these activities to correlate highly. As a result, some operationalizations of entrepreneurship might turn out to be better measures of the construct than others. However, this is true of *any theory* to explain who becomes an entrepreneur, not just a test of genetic factors.[9]

Fifth, we focus our attention on the four different mechanisms through which genetic factors operate, rather than on a lower level of analysis, such as identifying the specific individual differences through which genetic factors might operate, for three reasons. One, most scholars' intuition of the role of genetic factors immediately focuses on the mechanism of genetic covariance with individual differences. Hence, we are afraid that focusing on specific propositions for how genetic factors operate through different individual differences – even if it were the most plausible of the four mechanisms that we propose – would close off inquiry in the other mechanisms and would encourage future scholars to focus exclusively on this mechanism.

Two, at this point in time, we have virtually no direct evidence for genetic covariance between entrepreneurship and specific individual differences. Thus, any evidence of genetic covariance with specific individual differences that exists today rests on the indirect evidence of an association between genetic factors and a specific individual difference in one study, and an association between that individual difference and the tendency to engage in entrepreneurship in another. Because geneticists have found evidence of the heritability of a wide variety of individual differences, the formulation of propositions for specific individual differences would reduce to identification of those individual differences that entrepreneurship researchers agree are robustly associated with the tendency to engage in entrepreneurship. Given the

[7] This paper represents the first attempt to discuss the possible influence of genetic factors on entrepreneurship. We do not believe that it is possible discuss the range of ways that genetic factors influence all aspects of entrepreneurship in a single paper. We recognize that many scholars might view other aspects of entrepreneurship to be more worthy of attention than the issue on which we have chosen to focus this paper. We offer two reasons for our selection. First, genes are attributes of people. Therefore, it is logical to think that they have a first order effect on aspects of the entrepreneurial process that are the direct result of human agency (like the decision to engage in entrepreneurial activity) rather than on the aspects of the process that are not the direct result of human agency (like the amount of venture capital in an economy or the presence of high growth industries). Second, performance at entrepreneurial activity is conditional on engaging in entrepreneurial activity. Therefore, it seems logical to investigate genetic factors that might influence the decision to engage in entrepreneurial activity before one investigates whether genetic factors influence success at that activity.

[8] While our focus abstracts away from the complexity of potential opposing effects on different aspects of the entrepreneurial process, it is important to note that this simplifying assumption is not specific to genetic factors. Any factor can have a positive effect on one aspect of the entrepreneurial process and a negative effect on another. For example, overconfidence has been shown to be positively associated with the tendency of people evaluate entrepreneurial opportunities favorably (Busenitz and Barney, 1997) and negatively associated with the likelihood that people will obtain financial resources for their ventures (MacMillan and Subba Narasimha 1987). Therefore, just as other researchers have made the simplifying assumption that the factors that they sought to predict influence the tendency of people to engage in entrepreneurial activity in ways that do not vary across the different aspects the entrepreneurial process (e.g., the identification of opportunities, the evaluation of business ideas, resource acquisition, the exploitation process, and so on), we assume that the mechanisms through which genetic factors influence the tendency of people to engage in entrepreneurship are the same, even though, in practice, they *might differ* across different parts of the process.

[9] For instance, research shows that certain social network positions are associated with being an owner–operator but are not associated with transition into self-employment (Aldrich and Kim, 2007; Stuart and Sorenson, in press). The inconsistent results do not falsify the social network theory of who becomes an entrepreneur because being an owner–operator might be the correct operationalization of the construct of entrepreneurship while self-employment might not be.

disagreement within the field of entrepreneurship over which individual differences have a robust association with the tendency to engage in entrepreneurship[10] (because of conflicting empirical results, the use of convenience samples, and different definitions of the experimental and control groups)[11], this effort would likely consist of a discussion of those individual differences that the authors, editors and reviewers of the paper *agree* are important, and which at least some future readers would not.

Because our proposed theory is not conditional on the inclusion of specific individual difference and environmental variables, we are selective in our discussion of specific genes, environmental conditions, and individual differences. Those that are discussed should be seen as examples of the mechanisms we propose rather than as a comprehensive discussion of how genetic factors influence the tendency of people to engage in entrepreneurial activity.

4. The influence of genetic factors on entrepreneurial activity

In this section, we provide a process theory for how genetic factors might influence the tendency of people to engage in entrepreneurial activity and develop specific propositions for four mechanisms through which genetic factors might influence this tendency: 'direct' effects, genetic covariance between individual differences and entrepreneurial activity, gene–environment interactions, and gene–environment correlations (see Fig. 1).

4.1. The physiological effects of genes

Genes might affect chemical mechanisms in the brain to increase the *likelihood* that people will engage in entrepreneurial activity. Although we currently know very little about the mechanisms through which genes directly affect social outcomes, researchers have proposed the physiology of brain function as the most likely mechanism. For example, researchers have shown that the *GABRG3* gene affects an inhibitory neurotransmitter in the human central nervous system, which governs the tolerance to and dependence on alcohol (Dick et al., 2004). By analogy, we reason that genes might affect the tendency of people to engage in entrepreneurial activity by influencing the level of positive or negative physiological reactions to that activity.[12]

We illustrate how the process might work by focusing on examples of genes that have been shown to affect related human activities. For instance, a polymorphism in the *5-HT$_{2c}$* gene, which is involved in the production of oxytocin, influences the physiological response that people have to overcoming obstacles, with those having the gene experiencing a greater positive physical response to such activity (Bagdy et al., 1992). Because researchers have shown that entrepreneurial activity involves significant persistence in overcoming obstacles to many things, including obtaining financing, hiring employees, and securing equipment and facilities (Baron and Markman, 2003; Baum and Locke, 2004; Baum et al., 2001; Markman and Baron, 2003), it is possible that the 5-HT$_{2c}$ polymorphism increases the likelihood that people engage in entrepreneurial activity by increasing the positive physiological response that those people have to it.[13]

[10] The evidence in support of the effects of individual differences that received widespread attention in the literature in the 1960's and 1970s (e.g., McClelland, 1961; Hornaday and Aboud, 1971) was heavily criticized in the 1980s and 1990s, when a number of papers reported contradictory empirical evidence (e.g. Brockhaus, 1980; Sexton and Bowman, 1983; Brockhaus and Horwitz, 1986; Chell et al., 1991; Cooper and Gimeno-Gascón, 1992), leading many scholars to discount individual differences research in entrepreneurship (Gartner, 1989; Low and MacMillan, 1988). However, recently some rigorous meta-analytic studies have reinvigorated interest in the personality characteristics of entrepreneurs by presenting significant associations and challenging the earlier narrative reviews (Collins et al., 2004; Rauch and Frese, 2000; Stewart and Roth, 2004; Baum et al., 2007). Moreover, researchers have also reframed their view of individual differences to incorporate dimensions other than personality traits, which has yielded stronger empirical findings (Baron, 2002).

[11] For instance, the entrepreneurship literature does not agree on a definition of entrepreneurship. These definitions range from self-employment (Evans and Leighton, 1989), to owning a business, to firm formation (Gartner, 1989), to engaging in the firm start-up process (Reynolds et al., 2004). The literature also disagrees on whether managers, employees, or the general population is the appropriate control group to compare entrepreneurs against.

[12] We are *not* suggesting that there is a single gene that captures a significant part of the variance in entrepreneurship, just as researchers do not argue that a single gene captures a significant part of the variance in alcoholism. We are merely pointing out that genes might affect the variance in entrepreneurship through chemical mechanisms in the brain, just as genes affect the variance in alcoholism through chemical mechanisms in the brain.

[13] The effect of this gene may be pleiotropic. The same 5-HT$_{2c}$ polymorphism would increase the likelihood that a person engages in, say, managerial activity and mountain climbing because the physiological response to the production of oxytocin would be experienced when any obstacles are overcome.

Similarly, a polymorphism in the *DRD4* gene, which has been associated with Attention Deficit Hyperactivity Disorder (LaHoste et al., 1996; Thapar, 2003), affects the release of dopamine in the brain (Van Tol et al., 1991, 1992). The release of dopamine influences, among other things, the physiological sensations that people feel from engaging in the same activity for long periods of time, as well as from action-oriented behavior. The evidence of greater action orientation and preference for engaging in multiple activities for short periods of time shown by entrepreneurs (Baron, 2002) might reflect their greater tendency to possess this polymorphism in the *DRD4* gene and its effect on the release of dopamine from taking action as well as engaging in the same activity for a long period of time. These arguments lead to the first proposition:

Proposition 1. *Genetic factors influence the tendency of people to engage in entrepreneurial activity through physiological effects that result from brain chemistry.*

4.2. Genetic covariance between individual differences and entrepreneurial activity

Genetic factors also (or alternatively) might predispose people to develop individual attributes that affect the tendency of people to engage in entrepreneurial activity. These individual attributes include, but are not limited to, personality traits, and also include such attributes as cognitive processes and attitudes (Baron, 2002). As we mentioned earlier, we do not have direct empirical evidence that genetic factors increase the tendency of people to engage in entrepreneurship through their effects on individual differences, and we are not proposing that *specific* individual differences are more likely to be the mediating variables than others. Rather, we are merely showing the plausibility of the mechanism of genetic covariance with individual differences.

To date, researchers have identified an association between genetic factors and a number of individual differences for which other researchers have identified an association between the individual difference and the propensity to engage in entrepreneurial activity. For example, a number of studies have shown the heritability of internal locus of control — a belief that outcomes can be controlled by one's own behavior (Rotter, 1966). For example, Pedersen et al. (1989) showed that additive genetic sources of individual variability in locus of control accounted for 31 to 34% of the variance, while heritability estimates based on monozygotic[14] twins reared apart yielded almost identical figures (32–36%), and a study by Miller and Rose (1982) showed heritability estimates of internal locus of control of 0.55.

A recent review by Rauch and Frese (2000) summarized evidence that internal locus of control is positively associated with a person's propensity to engage in entrepreneurial activity (see also studies by Durand, 1975; Caird, 1991; Ahmed, 1985; Cromie and O' Donaghue, 1992; Ward, 1993). Moreover, Schiller and Crewson (1997) analyzed data from the National Longitudinal Survey of White Men (1966–1981) and found some evidence that individuals with more internal locus of control, as measured in their youth, exhibited a higher likelihood of transitioning to self-employment later in life, indicating that internal locus of control is the cause, not the effect, of entrepreneurial activity.

A second individual difference that has been associated with both genetic factors and the propensity of people to engage in entrepreneurial activity is extraversion. A number of studies have shown that extraversion – a personality trait that incorporates several attributes, including sociability, gregariousness, talkativeness and exhibitionism (Barrick and Mount, 1991) – is heritable (Bouchard and Loehlin, 2001). For example, a meta-analysis of 36 studies of monozygotic (MZ) and dizygotic (DZ) twins reared together found that the heritability for extraversion was 0.58 (Eaves et al., 1989), while other studies have found broad heritabilities of 0.53 (Jang et al., 1996), 0.49 (Waller, 1999), and 0.56 (Riemann et al., 1997). Moreover, molecular genetic studies of extraversion support the results of twin studies. Benjamin et al. (1996) found that the long alleles of the DRD4 exon III repeat gene were positively associated with extraversion. (Given that personality traits cannot alter gene sequence, empirical evidence of an association between genes and a personality trait can be interpreted as evidence of a genetic cause of the individual difference).

Several empirical studies provide evidence that extroversion is positively associated with the likelihood that people will engage in entrepreneurial activity.[15] For instance, Roberts (1991) examined 72 technologists within the MIT

[14] Monozygotic, or identical, twins arise when a single egg is fertilized by a single sperm, and thus are genetically identical. Dizygotic, or fraternal, twins, arise when two eggs are fertilized by two separate sperm, and so share, on average, 50% of their segregating genes.

[15] Extraversion increases the likelihood that people will engage in entrepreneurial activity, just as it increases the likelihood that people will engage in all activities (sales, acting, etc) in which persuading others is important. The entrepreneurial process depends heavily on convincing others – potential investors, employees and customers – of the value of a yet unproven idea (Baron and Markman, 2003). Sociability and expressiveness enhance the ability to do this (Bhide, 2000).

Enterprise Forum and the 128 Venture Group and found that those with stronger entrepreneurial tendencies were more extroverted than the others. Burke et al. (2000) used data from the National Child Development Study, which surveyed a cohort of individuals born in one particular week in March 1958 and found that individuals with a more extroverted orientation (higher anxiety acceptance scores) measured at the age 11 were more likely to become self-employed later in life.

A third individual difference for which there is evidence of genetic influence and association with the tendency of people to engage in entrepreneurial activity is need for achievement, a motivation that leads people to undertake activities and tasks that involve personal responsibility for outcomes, demand individual effort and skill, involve moderate risk and provide clear feedback (McClelland, 1965).[16] Several studies show evidence of the heritability of achievement motivation. Tellegen et al. (1988) found a heritability estimate of 0.39; while McGue et al. (1993), who administered the same questionnaire twice, ten years apart to a sample of twins, found an achievement score correlation of 0.40 between MZ twins when twin scores were measured at the same time. When they compared one twin's score at the time of first testing with the score achieved by his/her pair ten years later, and found a correlation of 0.24 for achievement. In other words, Harry's achievement score at the time of first testing was statistically predictive of Michael's score ten years later.

Empirical research also has shown an association between need for achievement and the tendency of people to engage in entrepreneurial activity. Meta-analyses by Collins et al. (2004) and Stewart and Roth (2004) have demonstrated a positive relationship between achievement motivation and the tendency to engage in entrepreneurial activity. (See also studies by McClelland, 1965, Hornaday and Bunker, 1970, Hornaday and Aboud, 1971, Begley and Boyd, 1986, Ahmed, 1985, Miner et al., 1989, and Cromie and O' Donaghue, 1992).

A fourth individual difference that is associated with both genetic factors and the propensity to engage in entrepreneurship is that of social potency/social skills. For instance, some researchers have shown that social skills are associated with the tendency to engage in entrepreneurial activity (Abell, 1996; Baron and Markman, 2003; Shane and Cable, 2002; Burt, 2005), while other researchers have shown evidence of the heritability of social skills. For example, Carey (2003) reported kinship correlations for social potency of 0.56 and 0.27 respectively for MZ and DZ twins reared apart and 0.65 and 0.08 for MZ and DZ twins raised together. These arguments lead to the second proposition:

Proposition 2. *Genetic factors influence the tendency of people to engage in entrepreneurial activity by accounting for part of the covariance between individual differences and the tendency of people to engage in entrepreneurial activity.*

4.3. Gene–environment interactions

Variance in the tendency of people to engage in entrepreneurship also might be explained by gene–environment interactions. *Gene–environment interaction* means that a gene creates sensitivity to a certain environmental stimulus (Rowe, 2003). When exposed to that stimulus, a person with the relevant gene displays a greater reaction than a person without that gene (Plomin, DeFries and Loehlin, 1977; Moffitt et al., 2005). Behavioral genetics research has provided evidence of the effect of gene–environment interactions on social outcomes. For example, Caspi et al. (2002) found that a functional polymorphism in the *MAOA* gene moderated the impact of childhood maltreatment on the development of anti-social behavior. That is, children with a particular polymorphism in the *MAOA* gene are more likely than children without this polymorphism to develop anti-social behavior if they are maltreated.

Researchers have not yet identified any gene–environment interactions that affect the tendency of people to engage in entrepreneurial activity. However, we can illustrate how this mechanism might operate by extrapolating from gene–environment interactions that affect related social outcomes. For example, the dopamine D4 receptor gene, which regulates dopamine in the brain, has been shown to increase the salience of information (Berridge and Robinson, 1998; Volkow, 2004). Because the identification of new business ideas is affected by both information about entrepreneurial opportunities and the salience of that information to the person receiving it (Gaglio and Katz, 2001; Shane 2000), people with a variant of the *DRD4* gene may be more sensitive than others to the stimulus of information about

[16] People who have a high need for achievement are argued to be more likely than others to become entrepreneurs because entrepreneurial activity involves solving ill-defined problems, goal setting and planning, and the drive to bring ideas to fruition.

potential business opportunities.[17] That is, the *DRD4* gene may interact with information about opportunities to increase the likelihood that a person will identify a new business idea, and so increase the probability that the person will engage in entrepreneurial activity.

Another example might be a polymorphism in the *5-HTT* gene, which has been associated with anxious behavior, negative emotionality, and hostility in response to unfamiliar situations (Lesch et al., 1996). Recently, this polymorphism was also found to moderate the influence of stressful events on depression (Caspi et al., 2003). Because the pursuit of some types of business opportunities is more stressful than others – for instance, quitting a tenured academic job to start a biotechnology firm to exploit research results involves making decisions that risk the loss of more wealth, time, and prestige under greater pressure and uncertainty than starting a part-time consulting business to exploit that research while maintaining a tenured professor – people with the long form of the *5-HTT* gene might be more sensitive than those without the gene to accept the stress of engaging in entrepreneurial activity when confronted with an opportunity to start a business that is of the more stressful variety.

A third example is the Taq A1 allele of the *DRD2* gene which has been shown to be more prevalent among excessive gamblers than the general population because the gene affects the reward pathways in the brain and reduce the physiological sensations that come from engaging in risky activity (Comings et al., 1996). Because the acquisition of capital is difficult due to the uncertainties and information asymmetries involved (Shane, 2003), entrepreneurs often need finance their ventures out of their own savings (Bates, 1995; Blanchflower and Oswald, 1998; Aldrich, 1999). It is possible that the possession of the Taq A1 allele *DRD2* gene might interact with the need to self-finance a business opportunity to affect the likelihood of person engaging in entrepreneurial activity. Those people who have this allele are more likely to engage in entrepreneurial activity when confronted with opportunity to start a business through self-financing. Although all of the findings referenced above would need to be replicated before researchers could conclude that the statements that they are shown to support are true, they nevertheless *suggest* our third proposition.

Proposition 3. *Genetic factors influence the tendency of people to engage in entrepreneurial activity through interactions with environmental factors.*

4.4. Gene–environment correlations

Genes influence exposure to environments, a phenomenon called *gene–environment correlation* (Plomin et al., 1977; Kendler and Eaves, 1986). Because genes lead people to select, modify and construct their environments (Scarr, 1992), environmental factors are non-randomly distributed among people of different genetic make-up (Neale and Maes, 2002)[18]. Thus, genes also might influence the tendency of people to engage in entrepreneurial activity through selection of people into different environments.

Although we do not have evidence yet of gene–environment correlations in the tendency of people to engage in entrepreneurial activity, we can propose some logical possibilities. For example, some people might be more likely to work in occupations or industries in which the odds of starting a business are higher because genetic factors affect their educational and occupational preferences. We know that the propensity of people to engage in entrepreneurial activity

[17] Research has shown that prior information about markets and prior information about how to serve markets increases the likelihood of identifying new business ideas (Shane, 2003). For instance, Shane (2000) found that prior knowledge about a market increases the likelihood of identifying an entrepreneurial opportunity in that market. This has been backed with some less direct evidence from Long (1982) and Boyd (1990) using immigrant data. Research also has shown that entrepreneurs often start companies to make similar products to those made by their former employers (e.g. Aldrich and Wiedenmayer, 1993; Klepper and Sleeper, 2001), often serve the same customers as their previous employers (e.g. Cooper and Dunkelberg, 1987), while the approaches that they employ are similar to those used by their former employers (e.g. Klepper, 2001). Furthermore, Cooper et al. (1991) found that the respondent's previous job was the most common source of the start-up's new business idea.

[18] There are three types of *genotype-environment correlation*: passive, active and evocative (Plomin et al., 1977, Rutter and Silberg, 2002). *Passive* genotype–environment correlation occurs when biological parents provide their children not only with genes conducive to the development of a particular trait but also with an environment that is favorable to the development of that trait. For example, intelligent parents might provide their children with both genes and the intellectually stimulating environment that is beneficial to the development of cognitive skills (Plomin et al., 1977). The *evocative* type "occurs when individuals evoke reactions from other people on their basis of their genetic propensities" (Plomin et al., 2001a,b: 309). For example, physically attractive children may encounter more positive reactions than less attractive children (Rowe, 2003) while "aggressive children provoke hostility among peers" (Gottfredson, 1999: 64). *Active* genotype–environment correlation occurs when individuals actively seek environments related to their genetic propensities (Plomin et al., 1977). That is, the active type occurs when individuals select, modify or construct their experiences based on their genetic propensities (Plomin et al., 2002).

varies across industries (Taylor, 1996). More than 80% of all firms are founded in the same industry in which the founders were previously employed (Young and Francis, 1991) and more than 60% of firm founders serve the same or similar customers as their prior employers (Cooper and Dunkelberg, 1987).

Moreover, the skills demanded of employees vary greatly across industries. People with strong mathematical skills will be more likely to be found employed in some industries (e.g., aerospace), while people with strong verbal skills will be more likely to be found employed in others (e.g., retail) (Eckhardt and Shane, 2005). Therefore, the likelihood that a person will engage in entrepreneurial activity could be affected by the industry in which a person is employed, which in turn could be affected by the skill set demanded by that industry.

Genetic factors influence the skills that people have. Researchers have shown that both verbal and mathematical skills are heritable. For example, Nichols (1978) found that the average twin correlations for verbal comprehension were 0.78 for MZ and 0.59 for DZ twins across 27 studies and 0.70 and 0.47 for MZ and DZ twins respectively for mathematical skills across 15 studies. Similarly, two other studies, by McGue and Bouchard (1989) and by Pedersen et al. (1992) reported heritability estimates of 0.57 and 0.58 respectively for verbal ability, while the heritability estimates for the measure of arithmetic and number comparisons were 0.53 and 0.58.

Thus, genetic factors might affect the skills that people have, which lead them to select into employment in different industries. Because different industries present different opportunities for engaging in entrepreneurial activity, gene–environment correlations in skills influence the tendency of people to engage in entrepreneurial activity.

Another example of how gene–environment correlations might influence the tendency of people to engage in entrepreneurial activity lies with education. People are more likely to engage in entrepreneurial activity if they are more highly educated.[19] A large number of studies have provided consistent evidence of the positive association between education and entrepreneurial activity (see Borjas, 1986; Macpherson, 1988; Borjas and Bronars, 1989; Boyd, 1990; Fernandez and Kim, 1998; Delmar and Davidsson, 2000; Davidsson and Honig, 2003; Rees and Shah, 1986; and Ritsila and Tervo, 2002).

There is also empirical evidence that genetic factors influence the number of years of education that people get (Taubman, 1976; Lichtenstein et al., 1992) and that genetic differences explain a significant amount of the variation in educational attainment (Behrman and Taubman, 1989). Because people with greater education are more likely than others to engage in entrepreneurial activity, gene–environment correlations could influence the tendency of people to engage in entrepreneurial activity. These arguments lead to the fourth proposition:

Proposition 4. *Genetic factors influence the tendency of people to engage in entrepreneurial activity through selection of people into different environments.*

5. How research on the genetic foundations of behavior can be used to understand entrepreneurship

This section explores different ways that the potential contribution of genetic factors to the tendency to engage in entrepreneurial activity may be assessed. The first approach, known as *quantitative genetics*, estimates genetic and environmental contributions to phenotypic variance in a population from patterns of genetic relationships among individuals, and usually involves the use of twin and adoption studies (Plomin et al., 2001a,b). The second approach, known as *molecular genetics*, identifies specific genes that contribute to variation between individuals in some social outcome. These two approaches to research are complementary because "twins make it possible to use quantitative genetic analyses that can chart the course for molecular genetic analyses" (Plomin et al., 2003: 536).[20]

[19] Education provides information and skills that increase the expected returns to entrepreneurial activity. Many of the skills necessary to start a business – those related to assembling resources, hiring people, targeting markets, selling, leading others, planning, organizing, making decisions, negotiating, problem solving and communicating – are learned in school (Shane, 2003). Education also provides the background knowledge necessary to notice new business opportunities (Shane 2000), as well as the analytic skills to evaluate them (Clouse, 1990). Finally, education provides social networks and legitimacy that are useful for many aspects of entrepreneurial activity, such as hiring employees and raising money (Thornton and Flynn, 2003).

[20] For many phenotypes finding the actual genes involved has proved very difficult, even though there has been consistent evidence of heritability. Given how difficult this has proved for a phenotype as straightforward as height, it is likely to prove very difficult for a less straightforward phenotype like engaging in entrepreneurial activity.

5.1. Quantitative genetics

There are certain "experiments of nature" and certain "experiments of nurture" that permit us to disentangle genetic from environmental contribution to human behavior. Specifically, studies of MZ and DZ twins and adoption can be used to separate these effects and have been used extensively in quantitative genetics research (Plomin et al., 2001a,b; Bouchard et al., 1990; DeFries et al., 1994).

5.1.1. Adoption studies

Adoption gives rise to 'genetic' parents (birth parents who give their children for adoption shortly after birth) and 'environmental' parents (the adoptive parents that have no genetic relation to their adopted children) (Plomin et al., 2001a,b). A correlation between genetic parents and their adopted-away children on some attribute can only be attributed to genetic factors, while, in the absence of a selected environment, similarity between adoptive parents and adopted children is environmentally related.

Genetic influence may also be evaluated by comparing the correlation between 'genetic-plus-environmental' parents[21] and their children on some attribute with the correlation between adoptive parents and their children on the same attribute (Plomin et al., 2001a,b). In the case of entrepreneurial activity, researchers can compare the correlation in the rate of self-employment, for example, between 'genetic-plus-environmental' parents and their offspring with the correlation between adoptive parents and their adopted children. If the correlation is higher between children and their 'genetic-plus-environmental' parents than it is between adopted children and their adoptive parents, then researchers would have evidence that self-employment has a genetic component.[22]

5.1.2. Twin studies

An alternative method for separating genetic and environmental influences involves studies that compare identical twins (MZ) with fraternal (DZ) twins. MZ twins share exactly the same genetic make-up, whereas DZ do not. If genetic factors are important in explaining behavioral variance, then MZ twins must be more similar than DZ twins. Therefore, researchers can use studies that compare identical (MZ) and fraternal twins (DZ) to disentangle the effects of genes and environments on the tendency to engage in entrepreneurial activity. For example, researchers can evaluate whether genetic factors influence the likelihood that people become entrepreneurs by comparing the rates of entrepreneurial activity among MZ and DZ twins. If the correlation between rates of entrepreneurial activity of dyads of MZ twins is higher than the correlation between the self-employment rates of dyads of DZ twins, then researchers would have evidence that the tendency to engage in entrepreneurial activity has a genetic component.[23]

5.1.3. Twin and adoption studies

Researchers can use a combination of twin and adoption methods in their research designs. For example, researchers can examine twins separated at infancy and raised apart, and twins raised together. By comparing the correlations between four different types of twins, MZ twins raised together, MZ twins raised apart, DZ twins raised together, and DZ twins raised apart, researchers can uncover the heritability of the tendency of people to engage in entrepreneurial activity. Because the differences between MZ and DZ twin correlations provide information about the effect of similar genetic make-up on the tendency to engage in entrepreneurial activity, and the differences between being raised together and being raised apart provide information about the effect of the environment on the tendency to engage in entrepreneurial activity, the combination of twin and adoption studies would allow researchers to compare the relative importance of environmental and genetic factors on dependent variables like self-employment.

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[21] 'Genetic-plus-environmental' parents share both genes and environment with their children.

[22] Because adoption is a non-random event, researchers need to exercise caution with studies of entrepreneurship based on adoption. If adoptive parents are more committed to their children than other parents, they might expose their children to more environmental influences that positively affect entrepreneurial activity (for example, education), thereby leading researchers to overstate the environmental affects on self-employment from adoption studies.

[23] Researchers need to exercise caution with studies of entrepreneurship based on twin studies. If studies are done in environments where entrepreneurship is very common, like the United States, the rates of entrepreneurial activity of MZ and DZ twins are more likely to look different than in environments, like Japan, where entrepreneurship is relatively rare. Therefore, researchers need to focus on the *difference* between the MZ and DZ twin correlations, and not in the correlations themselves.

5.2. Molecular genetics

The second method that can be used to assess the contribution of genetic factors to entrepreneurship is *molecular genetics*. In contrast to quantitative genetics, molecular genetics tries to identify specific genes that are responsible for individual differences in behavior. It does so by analyzing DNA (Watson and Berry, 2003).

There are two major methods that are used in molecular genetics research: linkage and association. *Linkage* analysis "typically uses phenotypic data on families to infer the presence and extent of non-independent segregation between a trait and one or more genetic markers, to establish the location of a trait-influencing genetic variant" (Sham, 2003: 41). To put it differently, linkage analysis identifies the co-transmission within families between an attribute and various genetic markers (Plomin and Walker, 2003) (linkage studies usually use many genetic markers with no specific hypotheses involved). Thus, researchers could investigate the co-transmission of DNA markers and the tendency to engage in entrepreneurial activity within families to generate evidence of the genetic basis for entrepreneurship.

Association, on the other hand, is a correlation between a *particular* DNA marker and an attribute in a population (Plomin et al., 2001a,b; Plomin and Spinath, 2004). To measure association, researchers compare an 'affected' sample that exhibits a particular characteristic to a control sample to determine whether there is an increased prevalence of a specific hypothesized DNA marker in the affected group (DiLalla, 2004). To generate evidence of the genetic basis for the tendency of people to engage in entrepreneurial activity through association analysis, researchers could compare hypothesized DNA markers of people who engage in entrepreneurial activity and people who do not. For example, researchers could identify an allele associated with entrepreneurial activity if people who engage in that activity also have that particular allele significantly more often than the general population.[24]

5.3. Detecting gene–environment interactions

Investigating gene–environment interactions in the tendency of people to engage in entrepreneurial activity would involve identifying both candidate genes and plausible environmental factors. For example, researchers might examine whether the interaction of the Taq A1 allele of the *DRD2* gene (which has been (inconsistently) associated with sensations of pleasure in response to excessive gambling) and the opportunity to start a business that requires self-financing increase the likelihood of engaging in entrepreneurial activity.

When examining gene–environment interactions, researchers should take three key considerations into account. First, researchers should select genes whose polymorphic variants are relatively common in the population. Second, they should choose genes for which a biologically plausible argument can be made for moderating the influence of the environmental measure. Third, an association between a gene and the tendency of people to engage in entrepreneurial activity is not a necessary condition for selecting a gene as a candidate for gene–environment interactions (Moffitt et al., 2005, 2006) because a gene's association with the tendency of people to engage in entrepreneurial activity may be conditional on the environment, making direct statistical associations between the gene and the tendency to engage in entrepreneurial activity difficult to uncover.

Researchers could test for evidence of gene–environment interactions in the tendency of people to engage in entrepreneurial activity though moderated regressions that focus on the interaction between a genetic polymorphism and an environmental variable (with a measure of entrepreneurial activity as the dependent variable). This would entail a four part process. The first part would involve the selection of a candidate gene for which DNA samples would be collected and sent to a lab for genotyping. The second part would involve operationalizing the select gene for statistical analysis based on the number of different variants that exist for that particular gene. The third part would involve selecting and gathering data on an environmental variable that has been linked to the tendency of people to engage in entrepreneurial activity and for which a biologically plausible relationship with the selected gene can be made. The fourth part of the process would entail examining whether the interaction between the genetic and the environmental variables was statistically significant in the regression analysis.

[24] Association studies are more likely than linkage studies to be useful in entrepreneurship research because they are more powerful in detecting alleles of small effect size and because association samples are more easily identified.

5.4. Detecting gene–environment correlations

There are two ways in which researchers can investigate the existence of gene–environment correlations in entrepreneurship: through correlations between attributes of biological parents and adoptive families' environments, and through multivariate genetic analysis of the relationship between an environmental measure and a correlated measure.

5.4.1. Correlations between attributes of biological parents and adoptive families' environments

Even though biological parents' attributes are not the best indicator of their adopted children's genotypes, a finding that biological parents' attributes are correlated with the environment in which the adoptive child lives suggests that the environment reflects genetically influenced characteristics of their adopted-away children (Plomin et al., 2001a,b). In the case of the tendency of people to engage in entrepreneurial activity, researchers could find evidence of gene–environment correlations by comparing the entrepreneurial activities of adopted children (which were separated at birth) with the characteristics of their biological parents. This would entail a two-part process. The first part would involve examining the correlation between biological parents' entrepreneurial activities and the adoptive parents' support of entrepreneurial activity. The second part would involve examining whether this correlation (i.e. between the biological parents' entrepreneurial activity and the adoptive parents' support of entrepreneurial activity) was reduced after including the adoptee's behavior as a mediating construct in the model. A reduced correlation would provide evidence of gene–environment correlation because the association between biological parents' entrepreneurial activities and the adoptive parents' behavior would be explained by the behavior of the adoptees (Baron and Kenney, 1986). (See Ge et al., 1996 and Riggins-Caspers et al., 2003 for applications of this methodology in different contexts, for example in the context of anti-social behavior).

5.4.2. Multivariate genetic analysis

In order to show a genetic effect on an environmental measure, it is not sufficient to show that the environmental measure is correlated with an individual attribute because such correlations may occur for environmental reasons. To detect such influences requires multivariate genetic analysis of the relationship between an environmental measure and a correlated measure (e.g., a psychological attribute). This technique examines the genetic and environmental contributions to the covariance between these two measures rather than to the variance of each measure considered on its own (Plomin and DeFries, 1979, Plomin, 1994). The essence of this method is to identify the extent to which genetic effects on an environmental measure overlap with the genetic effects on a correlated measure.

Fig. 2 illustrates the bivariate case. Latent variable *G* represents genetic influences on the environmental measure that overlap with the other measure, while latent variable *E* represents common environmental effects. The path from *G* to the environmental measure indicates genetic effects on the environmental measure that are shared with the genetic effects on the correlated measure (Plomin, 1994). The indicator *g* represents unique genetic effects on the environmental measure that are independent of the genetic effects on the correlated measure.

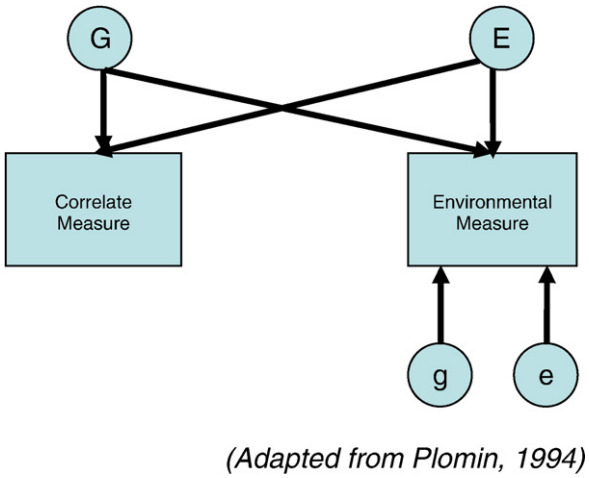

Fig. 2. Multivariate genetic analysis.

In the case of the tendency of people to engage entrepreneurial activity, multivariate genetic analysis can be used to identify whether the genetic variance of the tendency to engage in entrepreneurial activity is accounted for by other behavioral factors (such as having internal locus of control) or environmental measures (such as living in a place like Silicon Valley where many venture capitalists operate).

5.5. Difficulties in conducting behavioral genetics research in entrepreneurship

It is important to note that providing evidence of the effects of genetic factors on the tendency of people to engage in entrepreneurship will not be easy. First, rigorous genetics research, whether on entrepreneurship or anything else, requires samples that are representative of the populations from which they are drawn.

Second, evidence of heritability of entrepreneurship is a necessary but not sufficient condition to explain the role of genetic factors in entrepreneurship. Finding genetic influences on a phenotype does not help identify the specific genes involved, nor does it explain how genes affect the phenotype. Finding these influences merely helps researchers suggest plausible candidate genes to investigate through studies of gene–environment interactions.

Third, the observed effects of genetic influences may not be fixed over time or place. As Plomin et al. (2001a,b: 88) emphasizes, "heritability refers to the contribution of genetic differences to observed differences among individuals for a particular trait in a particular population at a particular time". Although the genetic composition that affects the probability that a person will engage in entrepreneurship does not change over his or her life, and the distribution of genes across the human population varies little over time (Strachan and Read, 2003), the *effect* of these genetic factors, and hence the observed phenotypes, can vary widely. In particular, if the primary mechanism through which genes affect the probability that will engage in entrepreneurship occurs through gene–environment interactions, then variation in the effects of the environmental stimuli that interact with a person's genetic composition can easily lead to very different distributions in the amount of entrepreneurial activity across time or locations for two populations with the identical distribution of genetic factors. As Baumol (1990) so clearly points out, people with a tendency to engage in entrepreneurship *for whatever reason* may be more likely to engage in activities like starting businesses in places in which environmental stimuli encourage such activity than in places where environmental stimuli discourage it. Thus, in any given population, the magnitude of the environmental effect can be larger or smaller than the magnitude of the genetic effect.

Moreover, while genes themselves are stable within people over their life course, the effects of genetic factors may increase or decrease over time. Genetic effects might increase because genetic effects snowball during development, leading to greater and greater phenotypic effects. Genes might be expressed under some conditions and at some times in development and not at others. Genetic effects also might increase or decrease because increased exposure to environmental factors over time may allow the effect of environmental factors to increase or even cumulate (Plomin et al., 2001a,b). For instance, in the case of entrepreneurship, the effect of genetic composition on the probability that a person engages in entrepreneurship might increase as a person ages because genetics influences the environmental conditions into which a person selects, generating a corridor of choices that increase the probability of becoming an entrepreneur. Conversely, the effect of genetic composition on the probability of becoming an entrepreneur might decrease as a person ages because increased exposure to the environment might lead environmental factors, such as education or work experience, to account for more of the variance in behavior.

Fourth, a substantive understanding of the role of genetics in entrepreneurship requires the accumulation of consistent results in multiple studies of samples representative of known populations; evidence of the mechanisms through which genetic factors influence the tendency to engage in entrepreneurship; and molecular genetics studies which identify the set of genes that operate through these mechanisms. It also demands replication of any associations found between candidate genes and entrepreneurship, a non-trivial achievement given the substantial number of studies that show a relationship between candidate genes and social outcomes similar to entrepreneurship that have not survived the test of *replication* (Kluger et al., 2002; Kendler, 2005a; Munafo et al., 2003).

6. Potential implications for entrepreneurship research

Research on genetic factors has potential implications for many aspects of entrepreneurship research. Space limitations preclude a discussion of all research issues that genetic research could possibly inform. Therefore, we merely provide several examples of potential research implications.

First, research on genetic factors might help to reinvigorate a longstanding, but not universally agreed upon, aspect of entrepreneurship research: the role of individual differences in the tendency of people to engage in entrepreneurial activity. Although much of the entrepreneurship literature considers entrepreneurship to be affected by both individuals and environments (Shane and Venkataraman, 2000), it does not agree on the relative importance of the two contributors (Gartner and Carter, 2003). Moreover, in recent years, the field has tended to focus less and less on the role of individuals and more and more on the role of environmental conditions in explaining the tendency of people to engage in entrepreneurial activity (Thornton and Flynn, 2003).

Because researchers have not explained all of the variance in the tendency of people to engage in entrepreneurial activity, and because many scholars believe that environmental factors alone cannot explain all of this variance (Shane and Venkataraman, 2000; Baron, 2004; White et al., 2006), research on genetic factors would be a welcome contribution to the entrepreneurship field if it would help to explain why individual differences, such as internal locus of control, or extraversion, are associated with entrepreneurial activity. Moreover, this research might provide an explanation for why certain individual differences other than psychological traits increase the tendency of people to engage in entrepreneurial activity.

Second, multivariate genetic analysis of the covariance between psychological traits (e.g. locus of control, extraversion) and entrepreneurship will inform scholars of the degree to which this covariance is explained by genetic or environmental factors.[25] Moreover, this information will enable researchers to identify whether the tendency to engage in entrepreneurial activity is affected by the same genes that affect various individual differences or whether it is affected by different genes.

Research into the effect of genetic factors on the tendency of people to engage in entrepreneurship also has the potential to indicate whether the association between individual differences and the tendency to engage in entrepreneurial activity is an artifact of omitted variable bias. For example, if the covariance between a personality trait and the tendency to engage in entrepreneurial activity was totally explained by genetic factors, an environmental stimulus to increase the predisposition to have this personality trait would not increase the propensity to engage in entrepreneurial activity. If research into genetic factors and entrepreneurship revealed that the association between psychological traits and the propensity of people to engage in entrepreneurial activity was such an artifact, then much of the extant theorizing about why and how individual differences explain entrepreneurial activity might need to change.

Third, research into genetic factors that influence the tendency of people to engage in entrepreneurial activity might improve the methodology of entrepreneurship research in several ways. For instance, it could help researchers to identify the appropriate comparison group for entrepreneurs. While some scholars compare entrepreneurs to managers (Brockhaus, 1980; Busenitz and Barney, 1997), other scholars compare entrepreneurs to the general population (Gartner and Carter, 2003), and the field has no consensus on what the appropriate control group is for entrepreneurs. Evidence of the pleiotropic effects of genes would help researchers to identify the right comparison group to use in their empirical research. For any study of the effect of environmental factors on the propensity of people to engage in entrepreneurial activity (e.g., access to capital), the correct comparison group for entrepreneurs would be those people who engage in the other activity affected by the gene. For example, if the gene that increases the propensity to engage in entrepreneurial activity also increases the propensity to engage in management activity, then managers are the appropriate comparison group to test the effect of access to capital on the tendency to engage in entrepreneurial activity.

In addition, co-twin control designs (what entrepreneurship researchers would call fixed effects models within monozygotic (MZ) twins) could be used to estimate the impact of environmental factors on the tendency of people to engage in entrepreneurial activity. Within-MZ models can control for a wide range of factors (e.g. personality and capabilities due to genetic predispositions, the neighborhood in which the twins grew up, cohort effects, family environment and background) which would otherwise confound our estimates. Such models can be used to overcome the estimation problems caused in non-experimental data by unobserved endowments that simultaneously affect both the independent and dependent variables (Kohler et al., 2005). Such research using twin data might enable entrepreneurship scholars to construct more rigorous theoretical models about the relationship of, for example, such as education and training, on the likelihood of engaging in entrepreneurial activity.

[25] It is important to note that finding a genetic predisposition for a trait X, *and* finding an association between trait X and entrepreneurial activity does not necessarily imply a genetic influence on entrepreneurial activity. It is only through analysis of the genetic covariance between the trait and entrepreneurial activity that such a relationship can be established.

Fourth, genetics might inform research issues that are largely unanswered by other approaches. For instance, what is the mechanism through which parental self-employment influences children's propensity to become self-employed? There is strong evidence across a wide range of studies that the likelihood of engaging in entrepreneurial behavior increases with parental self-employment (Shapero and Sokol, 1982; de Wit and van Winden, 1989; Butler and Herring, 1991; Taylor, 1996; Burke et al., 2000; Uusitalo, 2001; Aldrich and Kim, 2007; Sorenson, 2007). For example, Fairlie (1999) examined a sample of 6417 employed men from the Panel Study of Income Dynamics and found that having a self-employed father increased the probability of self-employment. Similarly, de Wit and van Winden (1989) found that Dutch men who had self-employed fathers in 1952 were more likely to be self-employed thirty years later.

There are two possible explanations for why the children of self-employed parents are more likely than other people to become self-employed, but no existing empirical research has been able to disentangle these explanations. One possible explanation is that the children of the self-employed learn more about self-employment because of the information that they gather about how to run a business either actively or passively during their childhood (Krueger, 1993). Another possible explanation is that the children of the self-employed are more likely than the general population to have genotypes that predispose them to engage in self-employment.

Genetics could inform this issue by identifying the degree of passive gene–environment correlation in entrepreneurial activity. Passive gene–environment correlation refers to the joint transmission of genes and environment within families (Plomin et al., 1977; Carey, 2003) and occurs when biological parents provide their children not only with the genes conducive to the development of a particular behavior but also with an environment that is favorable to the development of that behavior. For example, self-employed parents might provide their children with both genes and the environment that is beneficial to the development of firm formation skills.[26]

Fifth, research into genetic factors has the potential to inform important debates in the scholarly literature about entrepreneurship. The most easily identifiable example concerns opportunity identification, which has been the subject of much recent discussion. Recent research has argued that the identification of new business opportunities is important to affecting who engages in entrepreneurial activity (Venkataraman, 1997; Shane and Venkataraman, 2000; Shane, 2003). However, the field is divided into two schools of thought about the nature of entrepreneurial opportunities. The first perspective argues that opportunities are concrete realities waiting to be noticed, or discovered, by entrepreneurs (Kirzner, 1997; Shane and Venkataraman, 2000; Gaglio and Katz, 2001). This perspective endorses an objective view of the environment where information exists independently of individuals "without a context of how and why individuals relate and interact to it" (Gartner et al., 2001:7).

Many researchers find this first perspective unsatisfying, arguing that opportunities are socially constructed, subjective *and* the product of an individual's actions (Gartner et al., 2001). This second perspective does not deny that concrete characteristics of an individual's environment exist and matter; but rather it argues that the environment is also determined by an individual's actions (Gartner et al., 2001). As Sarasvathy (2003: 308–9) argues, "opportunities and markets have to be invented, fabricated, constructed, made — through the peculiar processes of human action and interaction that comprise the entrepreneurial method".

The debate over the objectivity of opportunities could be informed by empirical examination of gene–environment correlations. Gene–environment correlations would provide support for the argument that opportunities are not independent of the individual who identifies them, making exposure to entrepreneurial opportunities non-random and subject to genotypic influence. As Scarr (1992) argues, gene–environment correlations view "human experience..... [as] the construction of reality, not a property of the physical world that imparts the same experience to everyone who encounters it" (Scarr, 1992, p. 5). If, entrepreneurial opportunities arise out of life's experiences and events (Gartner et al., 2001) which are, to some degree, genetically influenced, entrepreneurial opportunities are not truly independent of an individual and are non-randomly distributed across the population.

[26] Passive gene–environment correlations may be empirically detected by comparing correlations between a measure of the family environment and a measure of children's entrepreneurial propensity in adoptive and non-adoptive families. If the correlation between the family environment and a child's behavioral measure is larger in non-adoptive than in adoptive families, this suggests that passive gene-environment correlation is present for that particular measure (see Plomin et al., 1985). In this example, the presence of a gene-environment correlation would indicate that the mechanism through which having self-employed parents increases the probability of engaging in self-employment is both the transmission of genotypes that influence the propensity to engage in entrepreneurial activity and the effect of information that comes from being reared in an entrepreneurial environment.

Fig. 3 illustrates how one could investigate the genetic contribution to the identification of *entrepreneurial opportunities* by measuring genotype–environment correlations. In our example, we suggest two variables that researchers have found to be associated with the identification of entrepreneurial opportunities — intelligence and internal locus of control (Shane, 2003). The model decomposes the genetic variance into variance that is common to all three variables, namely G1, to variance that is common to the second and third variables, namely G2, and to variance that is unique to entrepreneurial opportunities, namely g. (the path diagram represents only one twin for simplicity — the full model would have the three variables for both twins as well as the appropriate covariance links between the latent variables). Genotype–environment correlation, and hence support for the opportunity enactment perspective, is shown if the genetic effects on the identification of entrepreneurial opportunities overlap with the genetic effects on the other measures.

Finally, if the influence of environmental factors on the tendency to engage in entrepreneurship is moderated by genetic factors, then the field's approach to government entrepreneurship policy and entrepreneurship education might need to be modified to accommodate these interactions. If, for example, the effect of external stimuli on the tendency to engage in entrepreneurship is contingent on an individual's genotypic profile, then government policies would need to be made more precise, essentially fitting policy stimuli to different genotypes. Similarly, a contingent influence of external stimuli on the tendency to engage in entrepreneurship would suggest that approaches to education also need to be fit to genotypes.

7. Conclusion

In this paper, we presented an argument for why researchers should examine the effect of genetic factors on the tendency of people to engage in entrepreneurial activity. We also proposed an explanation for how genetic factors might influence this tendency. We are not proposing that individuals are born with a 'gene for entrepreneurship', but rather that there are four complementary mechanisms through which genetic factors might affect the tendency of people to engage in entrepreneurial activity. We offered specific suggestions for how entrepreneurship researchers could use the methods of quantitative and molecular genetics to examine how genetic factors influence this tendency. We also explained how researchers could disentangle the effects of genetic and environmental factors in entrepreneurial activity. Finally, we discussed how research on genetic factors could inform entrepreneurship research.

Clearly, we are only suggesting where to start. At present, we have no direct empirical evidence that genetic factors affect people's propensity to engage in entrepreneurial activity. Such evidence would be necessary to determine the value of investigating the role of genetic factors in entrepreneurship, and the validity of the process theory we are proposing.

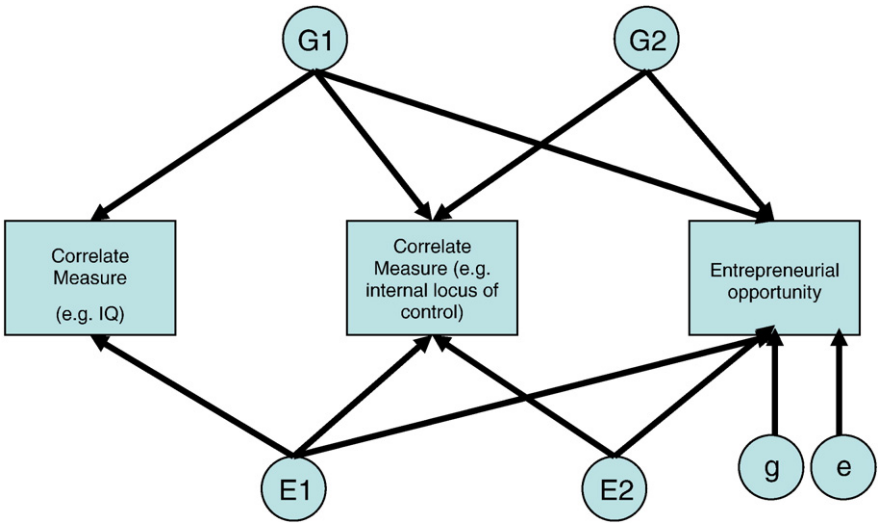

Fig. 3. Using genetic analysis in research on entrepreneurship.

We also have not mapped genetic factors to all aspects of entrepreneurship, focusing exclusively on the relationship between genetic factors and the tendency of people to engage in entrepreneurial activity. As theory develops in this area, we would expect researchers to explain ways in which genetic factors might influence the entire entrepreneurial process from the identification of opportunities, through the processes of resource assembly, organizing, and opportunity exploitation. For example, scholars might use genetic research to provide insights into the sources of competitive advantage for entrepreneurs (Alvarez and Busenitz, 2001).

As this journey unfolds, researchers may find that the investigation of the influence of genetic factors leads to a rethinking of scholarly explanations for entrepreneurship because it leads to arguments fundamentally different from those in the extant literature. Alternatively, such an investigation may provide only minor insights by enhancing and extending existing explanations for the phenomenon. We hope that this paper will lead other scholars to join us in our quest to further uncover the role of genetic factors in entrepreneurship and find out which of these paths such an investigation takes us down.

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