BORN ENTREPRENEURS? THE GENETIC FOUNDATIONS OF ENTREPRENEURSHIP

Nicos Nicolaou
Tanaka Business School, Imperial College London,
South Kensington Campus,
London, SW7 2AZ,
United Kingdom.
Tel: 44-20-75949499
Email: nicos.nicolaou@imperial.ac.uk

Scott Shane
Weatherhead School of Management,
Case Western Reserve University,
11119 Bellflower Rd.,
Cleveland, OH 44106.
Tel: 216-368-5538
Email: sas46@cwru.edu

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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 six 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 implications of a genetic perspective for management research on entrepreneurship.

EXECUTIVE SUMMARY

Entrepreneurship scholars have identified a variety of factors that explain why some people and not others engage in entrepreneurial activity (Shane, 2003). However, one of the most interesting explanations – genetic factors – has not been examined. In this paper we provide an argument for how genetic factors might influence the likelihood that people pursue entrepreneurial activity. Drawing on the behavioral genetics literature, we propose that genetic factors may influence the tendency of people to engage in entrepreneurial activity in six complementary ways. First, genes may have direct effects on chemical mechanisms in the brain that predispose some people and not others to engage in entrepreneurial activity. Second, genes may make some people more sensitive than others to environmental stimuli that increase the likelihood of engaging in entrepreneurial activity. Third, 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. Fourth, genes may influence exposure to environments that are more favorable to entrepreneurship. Fifth, the genes that predispose people to engage in entrepreneurial activity may also influence the tendency to engage in other social behaviors. Sixth, two or more genes may need to interact to influence the propensity for people to engage in entrepreneurial activity.

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

Finally, we discuss how research on genetic factors could inform entrepreneurship research. For example, behavioral genetics could inform research on the objectivity or subjectivity of entrepreneurial opportunities, the mechanism through which parental self-employment influences children's propensity to become self-employed (Aldrich and Kim, forthcoming), and the individual differences literature in entrepreneurship (Baron, 2004; White, Thornhill and Hampson, 2006).

For 40 years researchers have examined who becomes an entrepreneur (Gartner, 1988; Bird, 1989; Shane & Venkataraman, 2000; Aldrich and Martinez, 2001; Baron, 2004). 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). However, 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 do not reject the possibility that other factors, such as the exogenously determined external environment, also influence the tendency of people to engage in that activity. In fact, environmental factors probably explain a greater proportion of the variance in the tendency to engage in entrepreneurial activity than genetic factors. However, we believe that it is valuable to consider how genetic explanations *complement* environmentally-driven explanations for this 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 do not argue that genes *determine* who engages in entrepreneurial activity in the way that specific genes *determine* whether or not people will develop diseases, such as Huntington's disease (e.g. Gusella et al., 1983). Specific genes do not *cause* people to engage in social activities, like entrepreneurship. They may only increase the probability that people will engage in those activities (Plomin, 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".

We propose that genetic factors influence the tendency of people to engage in entrepreneurial activity in six complementary ways (see Figure 1). First, genes may have direct effects on chemical mechanisms in the brain to predispose some people to engage in entrepreneurial activity. Second, genes may make some people more sensitive than others to environmental stimuli that increase the likelihood of engaging in entrepreneurial activity. Third, genes may affect the tendency of people to select into environments that are more favorable to entrepreneurship. Fourth, genes may influence individual differences, such as extraversion and internal locus of control, that predispose people to engage in entrepreneurial activity. Fifth, the genes that predispose people to engage in entrepreneurial activity may also influence the tendency to engage in other social behaviors. Sixth, two or more genes may need to interact to influence the propensity for people to engage in entrepreneurial activity.

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.[1] In particular, the paper discusses how researchers can separate genetic from environmental influences, given the potential for gene-environment interactions and gene-environment correlations.

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 effect of genetic factors to the single issue of who engages in entrepreneurial activity, and leave the discussion of how genetic factors influence other aspects of the entrepreneurial process and the performance of entrepreneurs to future research.[2]

Understanding how genetic factors influence who engages in entrepreneurial activity is important for several reasons. First, understanding the role of genetic factors might lead to the

[1] Quantitative genetics involves inferring genetic effects from twin and adoption studies, while molecular genetics involves identifying specific genes that are responsible for an outcome.

[2] This paper represents the first attempt to discuss the 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 influence the decision to engage in entrepreneurial activity before one investigates genetic influences on success at that activity.

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 redress this imbalance by showing, for example, how genetic factors lead people to select into environments conducive to entrepreneurial activity.

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, forthcoming; Sorenson, forthcoming) is the result of information about how to run a business that is provided during childhood or whether it is the result of genetic factors.

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 specific genes 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 describes our process theory for how genetic factors influence the tendency of people to engage in entrepreneurial activity and develops specific

testable propositions about those mechanisms. The second section offers suggestions for how researchers might examine the influence of genes on the tendency of people to engage entrepreneurial activity. The third section discusses implications for entrepreneurship research. The fourth section concludes.

THE INFLUENCE OF GENES ON ENTREPRENEURIAL ACTIVITY

In this section, we provide a process theory for how genetic factors may influence the tendency of people to engage in entrepreneurial activity and develop specific propositions for six mechanisms through which genetic factors influence this tendency: direct effects, gene-environment interactions, genetic covariance between individual differences and entrepreneurial activity, gene-environment correlations, pleiotropy, and epistasis (see Figure 1). Following recent researchers, we define entrepreneurial activity as the recognition and exploitation of opportunities to bring new goods or services into existence (Venkataraman, 1997; Shane and Venkataraman, 2000). However, our theory would not change if we were to define entrepreneurship as self-employment (Fairlie, 1999; Burke et al., 2000) or new firm formation (Katz and Gartner, 1988; Aldrich, 1999).[3] Therefore, we do not offer any arguments that are conditional on entrepreneurial activity taking one of these particular forms.

Moreover, our theory is not conditional on the inclusion of specific candidate genes and individual difference variables. We seek to show how genetic factors can influence the tendency of people to engage in entrepreneurial activity, rather than discuss how every single plausible gene might influence this process. Therefore, we are selective in our discussion of candidate genes and individual difference variables. These should be seen as examples of the mechanisms we propose rather than as a comprehensive discussion of how genes influence the tendency of people to engage in entrepreneurial activity.

[3] Our theory describes the process through which genes affect people's tendency to engage in entrepreneurial activity. While the identification and exploitation of opportunity, the decision to found a firm, and the decision to become self-employed are different activities, the process through which genetic factors affects all of them is the same.

Direct Effects of Genes

Genes might affect the tendency of people to engage in entrepreneurial activity directly (see Figure 2). 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.

Although researchers have not yet developed direct evidence of the effects of specific genes on the tendency of people to engage in entrepreneurial activity, let alone shown the specific physiological mechanisms through which those effects operate, it is possible to identify some likely candidates for direct genetic effects by focusing on genes that have been shown to affect similar human activities. For example, the Taq A1 allele[4] of the DRD2 gene 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 thus the sensations of pleasure that come from engaging in risky activity (Comings et al., 1996). People with this gene do not experience gratification easily and manifest a marked propensity for seeking out risky activities. Entrepreneurship is a risky activity because entrepreneurs must make purchases for inputs used to create products and services before they know if they can sell those products or services at more than cost (Khilstrom and Laffont, 1979). Because of this, it is possible that people with this variant of the DRD2 gene are more likely than other people to have pleasurable sensations from engaging in entrepreneurial activity.

Another candidate for direct genetic effects is a polymorphism in the 5-HT_{2c} gene, which is involved in the production of oxytocin, which can influence 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). Researchers have shown that entrepreneurial activity involves significant persistence in overcoming obstacles to many things, including obtaining

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

financing, hiring employees, and securing equipment and facilities (Baron and Markman, 2003; Baum and Locke, 2004; Baum et al, 2001; Markman and Baron, 2001). Therefore, it is possible that people with the 5-HT_{2c} polymorphism are more likely to engage in entrepreneurial activity than the general population because the gene increases the positive physiological response that those people have to overcoming obstacles.

A third candidate for direct genetic effects is a polymorphism in the DRD4 gene, which has been associated with Attention Deficit Hyperactivity Disorder (LaHoste et al., 1996; Thapar, 2003). The DRD4 gene affects the release of dopamine in the brain (Van Tol et al., 1991, 1992), which influences, among other things, the ability of people to engage in the same activity for long periods of time, and predisposes people toward action-oriented behavior. Researchers have shown that entrepreneurs are more action oriented than the general population and have a preference for engaging in multiple activities for short periods of time (Baron, 2002). Thus, people with the DRD4 gene might be more likely than the general population to engage in entrepreneurial activity[5]. These arguments lead to the first proposition:

Proposition 1: Genetic factors influence the tendency of people to engage in entrepreneurial activity through direct effects.

Gene-Environment Interactions

Genes and the environment might act jointly to influence the tendency of people to engage in entrepreneurial activity, a mechanism called g*ene-environment interaction* (see Figure 3). *Gene-environment interaction* means that a gene creates a sensitivity to a certain environmental stimulus

[5] It is important to note that direct effects of genes do not mean that genes *cause* entrepreneurship. They only mean that genes influence the propensity of people to engage in entrepreneurship directly, rather than in interaction with other factors. 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, c*omplete 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 almost certainly a case of *incomplete penetrance* where this probability is significantly below 1.0.

(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; Mofitt 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 polymorphism in the MAOA gene moderated the impact of childhood maltreatment on the development of antisocial behavior. That is, children with the MAOA gene are more likely than children without the gene to develop anti-social behavior if they are maltreated.

Quantitative genetics (i.e. twin and adoption) studies have also yielded evidence of gene-environment interactions (e.g. Kendler et al., 1995; Heath et al., 1998; Rowe et al., 1999). For example, Rowe et al. (1999) found that parental education moderated the genetic influence on general cognitive ability. That is, the effect of genes on verbal IQ is higher for children who live in more educated households than for children who live in less educated households.

Researchers have not yet identified any gene-environment interactions that affect the tendency of people to engage in entrepreneurial activity. However, we can suggest some likely candidates based on gene-environment interactions that affect similar social outcomes. For example, studies have shown an association between the dopamine D4 receptor gene and novelty-seeking (Ebstein et al., 1996; Benjamin et al., 1996). The dopamine D4 receptor gene regulates dopamine in the brain, which 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 the DRD4 gene may be more sensitive than others to the stimulus of information about potential business opportunities. That is, the DRD4 gene interacts 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.

A second possibility is 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 engaging in entrepreneurship is stressful - it involves making

decisions that risk loss of wealth, time, and prestige under pressure and uncertainty (Baron, 2002) - people with the 5-HTT gene might be more sensitive than those without the gene to the stress of engaging in entrepreneurial activity. That is, the 5-HTT gene interacts with the stress of engaging in entrepreneurial activity to decrease the likelihood that a person with that gene will engage in such activity. These arguments lead to our second proposition.

Proposition 2: Genetic factors influence the tendency of people to engage in entrepreneurial activity through interactions with environmental factors.

Genetic Covariance between Individual Differences and Entrepreneurial Activity

Genes might predispose people to develop individual attributes that affect the tendency of people to engage in entrepreneurial activity (see Figure 4). These individual attributes include personality traits, but are not limited to them. They also include other attributes, such as cognitive processes and attitudes (Baron 2002).

To date, researchers have identified a genetic predisposition for a number of personality traits, which are also associated with the propensity to engage in entrepreneurial activity. For example, a number of studies have indicated a genetic predisposition to internal locus of control – a belief that outcomes can be controlled by one's own behavior (Rotter, 1966). Pedersen et al. (1989) showed that additive genetic sources of individual variability in locus of control accounted for 31 to 34 percent of the variance, while heritability estimates based on monozygotic[6] twins reared apart yielded almost identical figures (32-36%). Another study by Miller & Rose (1982) showed heritability estimates of internal locus of control of 0.55.

A recent review by Rauch & Frese (2000) summarized evidence (see also studies by Durand, 1975; Caird, 1991; Ahmed, 1985; Cromie & O'Donaghue, 1992; and Ward, 1993) that people with internal locus of control are more likely than other people to engage in entrepreneurial activity. Moreover, Evans & Leighton (1989) and Schiller & Crewson (1997) analyzed data from the National

[6] 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 percent of their genes.

Longitudinal Survey of White Men (1966-1981) and found 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 personality trait that has been associated with both genetic factors and the propensity of people to engage in entrepreneurial activity is extraversion. Extraversion is a personality trait that incorporates several attributes, including sociability, gregariousness, talkativeness and exhibitionism (Barrick & Mount, 1991). A number of studies have shown that extraversion is heritable (Bouchard & 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). Other studies have found broad heritabilities of 0.53 (Jang et al., 1996), 0.49 (Waller, 1999), and 0.56 (Riemann et al., 1997) respectively.

Molecular genetic studies of extraversion confirm the results of twin studies. Benjamin et al. (1996) found that the long alleles of the DRD4 exon III repeat 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 personality trait.

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).

Several empirical studies provide evidence that extroverted individuals are more likely engage in entrepreneurial activity than the general population. For instance, Roberts (1991) examined 72 technologists within the MIT 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 personality trait for which there is evidence of genetic origins and which has also been associated 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). People who have a high need for achievement are 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.

Several studies show evidence of the heritability of achievement motivation. Tellegen et al. (1988) found a heritability estimate of 0.39; while McGue, Bacon & Lykken (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 has shown an association between need for achievement and the tendency of people to engage in entrepreneurial activity. Meta-analyses by Collins, Hanges & Locke (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 & Bunker (1970), Hornaday & Aboud (1971), Begley & Boyd (1986), Ahmed (1985), Miner et al. (1989), and Cromie & O'Donaghue (1992)).

Not all individual attributes that predispose people to engage in entrepreneurial activity and are influenced by genetic factors are personality traits. Social skills are one example. Because much of the activity necessary to create businesses – hiring employees, raising money, identifying ideas, hiring employees – depends heavily on social networks (Thornton and Flynn, 2003), entrepreneurs need strong and broad social skills (Baron, 2002; 2004). Moreover, 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).

In turn, there is some evidence for 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 third proposition:

Proposition 3: 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.

Gene-Environment Correlations

Genes influence exposure to environments, a phenomenon called *gene-environment correlation* (Plomin, DeFries & Loehlin, 1977; Kendler and Eaves, 1986) (see Figure 5). 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 & Maes, 2002) [7]. Thus, genes also might influence the tendency of people to engage in entrepreneurial activity through selection of people into different environments.

Gene-environment correlations affect many human characteristics. For instance, researchers have shown that the heritability of general cognitive ability rises from about 0.20 in infancy to about 0.60 later in life (McGue et al, 1993) because people with genes that increase their general cognitive

[7] 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., 2001: 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).

abilities select, influence, and even create environments that are favorable to cognitive ability over their life course (Bouchard et al, 1997).

Gene-environment correlation might influence the likelihood that people engage in entrepreneurial activity. One example of how is through genetic influences on occupational choice. Different industries demand different skills among their employees. The distribution of types of jobs employees hold varies across industries – for instance, the semiconductor industry has a higher proportion of electrical engineers and technicians than the retail industry (Eckhardt and Shane, 2005) – leading the skill sets demanded of employees to vary across industries. As a result, people with strong mathematical skills will be more likely to be found employed in some industries, while people with strong verbal skills will be more likely to be found employed in others.

The propensity of people to engage in entrepreneurial activity varies across industries (Taylor, 1996). More than eighty percent of all firms are founded in the same industry in which the founders were previously employed (Young & Francis, 1991) and more than sixty percent of firm founders serve the same or similar customers as their prior employers (Cooper & Dunkelberg, 1987). Therefore, the likelihood that a person will engage in entrepreneurial activity is affected by the industry in which a person is employed, which in turn is affected by the skill set demanded by that industry.

This pattern is important because researchers have shown that 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 & 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 influence the skills that people have. These skills lead people to select into employment in different industries. Because different industries present different opportunities for engaging in entrepreneurial activity, gene-environment correlations 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. 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)

A large number of studies have provided consistent evidence of the positive relationship between education and entrepreneurial activity using US data (see Borjas, 1986 Macpherson, 1988; Borjas & Bronars, 1989; Boyd, 1990; Fernandez & Kim, 1998). These results have also been replicated in Sweden (Delmar & Davidsson, 2000; Davidsson & Honig, 2003), the United Kingdom (Rees & Shah, 1986) and Finland (Ritsila & Tervo, 2002). Additional support for the positive relationship between education and self-employment has been found in more macro-level studies of the correlation of the distribution of educated people and self-employed people across geographic locations (Guesnier, 1994; Bull & Winter, 1991).

There is also empirical evidence that education is affected by genetic factors. For example, Taubman (1976) found that the number of years of schooling exhibited considerable genetic influence. Lichtenstein & Pedersen's (1992) replicated this result with Swedish twins and Tambs et al's (1989) demonstrated this result with Norwegian twins. Behrman & Taubman (1989) estimated a model of educational attainment using data on kin groups related to a sample of US male twins, and found that genetic differences explained a significant amount of the variation in educational attainment.

Thus, genetic factors influence the level of education that people obtain. Because people with greater education are more likely than others to engage in entrepreneurial activity, gene-environment

correlations 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.

Pleiotropy

A gene that influences one social behavior may also influence another social behavior, a concept called *pleiotropy* (Plomin et al., 2001) (See Figure 6). For example, behavioral genetics researchers have found that the DRD4 gene influences both novelty seeking and attention deficit/hyperactivity disorder (Ebstein et al., 1996; LaHoste et al., 1996) while a polymorphism in the serotonin transporter gene influences both neuroticism and seasonal changes in mood (Sher et al., 2000).

There is a basic physiological reason to believe that genes that affect the tendency of people to engage in entrepreneurial activity are likely to be pleiotropic. Evidence from neural research indicates that the same dopamine reward mechanism in the brain is activated for many reinforcers (Montague and Berns, 2002), including eating food, taking illicit drugs, and making money (Schultz, 1997). Thus, genes that influence the release of dopamine in response to environmental stimuli might trigger a physiological reward that increases the propensity to engage in many activities, including entrepreneurial activity.

The pleiotropic effects of genes on social behavior are important because a gene that increases the propensity of people to engage in entrepreneurial activity might also increase the propensity of people to engage in other activities, such as managerial or criminal activity. Thus, pleiotropic effects would suggest the importance of environmental conditions in explaining entrepreneurial activity because the activities that would be influenced by a particular genotype would depend a great deal on interactions with environmental stimuli.

The potential for a gene to have pleiotropic effects on the propensity of people to engage in managerial and entrepreneurial activities is logical, given that both of these activities are business-

related. However, even the possibility that a single gene influences both a predisposition to engage in entrepreneurial activity and criminal activity may not be farfetched. Researchers have argued that entrepreneurial activity can take productive forms, like the creation of new high technology companies, or unproductive forms, like criminal activity, depending on the institutional environment in which entrepreneurs are found (Baumol, 1990). Moreover, at least one study provides empirical evidence that people who engage in one type of criminal activity, drug dealing, in their youth are more likely to become self-employed later in life, and that this effect is not the result of greater capital accumulation, incarceration, or limited wage employment opportunities among people who were once drug dealers (Fairlie, 2002). This argument leads to the fifth proposition.

Proposition 5: Genetic factors that influence the tendency of people to engage in entrepreneurial activity are pleiotropic.

Epistasis

Two or more genes often need to interact to create a propensity for a particular social outcome to occur, a concept that researchers call *epistasis* (Wolf et al., 2000; Grigorenko, 2003) (see Figure 7). For example, researchers have shown that an interaction between the 5HTTLPR and the COMT genetic polymorphisms is necessary to have a predisposition toward persistence (Benjamin et al, 2000).

Although researchers have not yet developed evidence of epistasis on entrepreneurship, it is possible to identify potential epistatic effects by focusing on those genes that have been shown to affect similar human activities. For example, Noble et al (1998) showed that people with both the DRD4 7 repeat allele and the 3 minor DRD2 alleles had higher novelty seeking scores than people with only one of these polymorphisms. Because novelty-seeking involves behaviors similar to those shown by entrepreneurs (Baron, 2002), such as trying “new things just for fun or thrills even if most people think it is a waste of time” and doing “things based on how I feel at the moment without thinking about how they were done in the past” (Ebstein et al, 2003: 367), these two genes might be

considered candidates for epistatic effects on the tendency of people to engage in entrepreneurial activity.

The epistatic effects of genes on social behavior have implications for how genes might influence the tendency of people to engage in entrepreneurial activity. Similar to other complex human outcomes, it may be that the genetic interactions have more of an effect on people's tendency to engage in entrepreneurial activity than the independent main effects of any one gene (Moore, 2003). Epistatic effects of genes on entrepreneurial activity may mean that instead of looking for a particular gene, researchers should be looking for a group of genes that, in interaction, affect the predisposition to engage in this activity. These arguments lead to the following proposition:

Proposition 6: Genetic factors that influence the tendency of people to engage in entrepreneurial activity are epistatic.

HOW RESEARCH ON THE GENETIC FOUNDATIONS OF BEHAVIOR CAN BE USED TO UNDERSTAND ENTREPRENEURSHIP

This section explores different ways that the 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 through the use of twin and adoption studies (Plomin et al., 2001). 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).

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., 2001; Bouchard et al., 1990; DeFries et al., 1994).

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., 2001). 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[8] and their children on some attribute with the correlation between adoptive parents and their children on the same attribute (Plomin et al., 2001). 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.[9]

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.[10] For example, researchers can evaluate whether genetic factors influence the likelihood that people become entrepreneurs by

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

[9] 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.

[10] Because identical twins are always of the same sex, comparison studies between MZ and DZ twins use same-sex DZ twins.

comparing the rates of self-employment among MZ and DZ twins. If the correlation between self-employment rates of dyads of MZ twins is higher than the correlation between the self-employment rate of dyads of DZ twins, then researchers would have evidence that self-employment has a genetic component.[11]

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.

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 & 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

[11] 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 self-employment rates of MZ and DZ twins are more likely to look different than in environments, like Japan, where entrepreneurship is relatively rare. However, this is unlikely to alter our conclusions as what we are interested in is the *difference* between the MZ and DZ twin correlations, and not in the correlations themselves.

analysis identifies the co-transmission within families between an attribute and a DNA marker (Plomin & Walker, 2003). Researchers can investigate the co-transmission of specific 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., 2001; Plomin & 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 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 the DNA markers of people who engage in entrepreneurial activity and people who do no. 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. [12]

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 look at the interaction of the Taq A1 allele of the DRD2 gene, which is associated with sensations of pleasure in response to risk taking, and the degree of risk involved in 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

[12] 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.

al., 2005) 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.

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.

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, 2001). 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 & 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).

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 genotype-environment correlations 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 & 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.

Figure 8 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.

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).

IMPLICATIONS FOR ENTREPRENEURSHIP RESEARCH

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

First, research on genetic factors can 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, plausibly increase the tendency of people to engage in entrepreneurial activity.

Second, investigation of *gene-environment correlations* 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 discussion. Recent research has argued that the identification of new business opportunities is important to affecting who engages in entrepreneurial activity (Venkataraman, 1997; Shane & 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 & Venkataraman, 2000, Gaglio & 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 can be informed by empirical examination of gene-environment correlations. Gene-environment correlations 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.

Figure 9 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.

Third, genetics can inform another research issue, which is concerned with 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 & Sokol, 1982; De Wit & Van Winden, 1989; Butler & Herring, 1991; Taylor, 1996; Burke et al, 2000; Uusitalo, 2001; Aldrich and Kim, forthcoming; Sorenson, forthcoming). 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 & 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 can 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.[13]

Fourth, 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[14]. This information will enable researchers to identify whether the tendency to engage in entrepreneurial activity is affected by the same genes that affect various personality traits and individual differences or whether it is affected by different genes. It 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.

Finally, research into genetic factors that influence the tendency of people to engage in entrepreneurial activity would also inform an important empirical issue in entrepreneurship research: the identification of the appropriate comparison group for entrepreneurs. Some scholars compare entrepreneurs to managers (Brockhaus, 1980; Busenitz and Barney, 1997), while other scholars compare entrepreneurs to the general population (Gartner and Carter, 2003). Evidence of the

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[13] 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.

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

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.

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. Rather than propose that individuals are born with a 'gene for entrepreneurship', we identified six 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 can use the methods of quantitative and molecular genetics to examine how genetic factors influence this tendency. We also explained how researchers can 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 genes 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.

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 genetic foundations of entrepreneurship and find out which of these paths such an investigation takes us down.

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FIGURE 1
Mechanisms Through Which Genetic Factors Influence Entrepreneurship

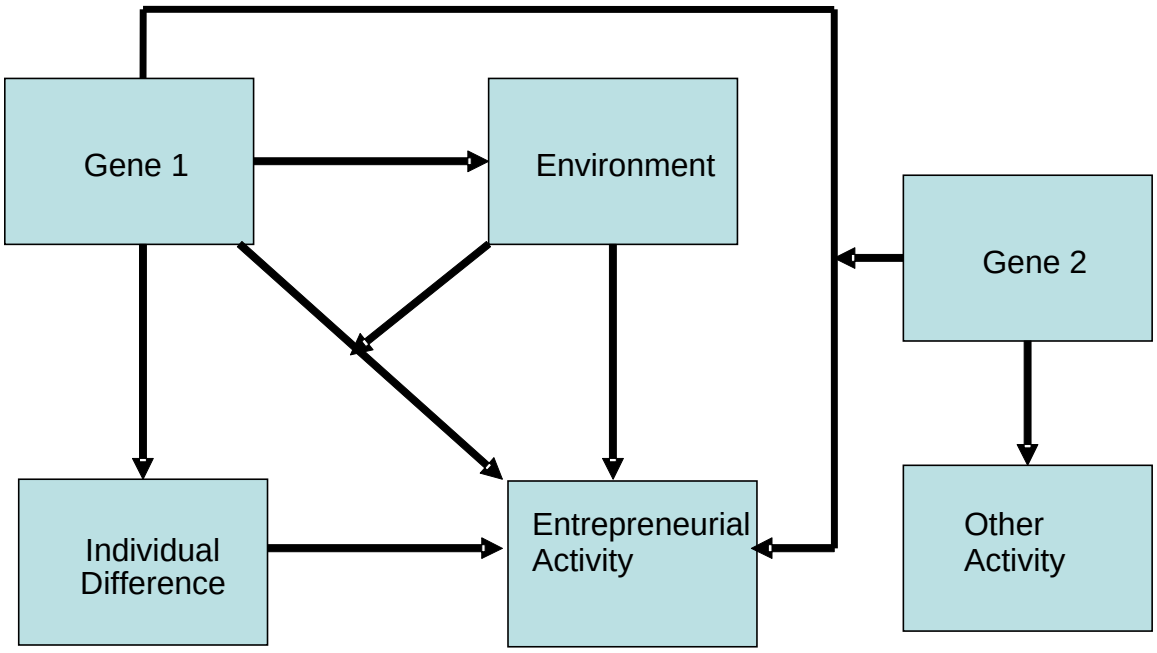


FIGURE 2
Direct Genetic Effects

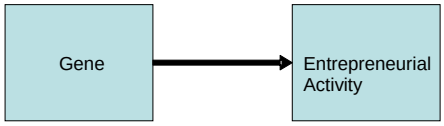


FIGURE 3
Gene-Environment Interactions

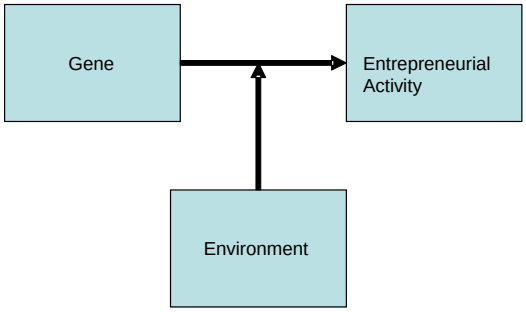


FIGURE 4
Genetic Covariance Between Individual Differences and Entrepreneurship

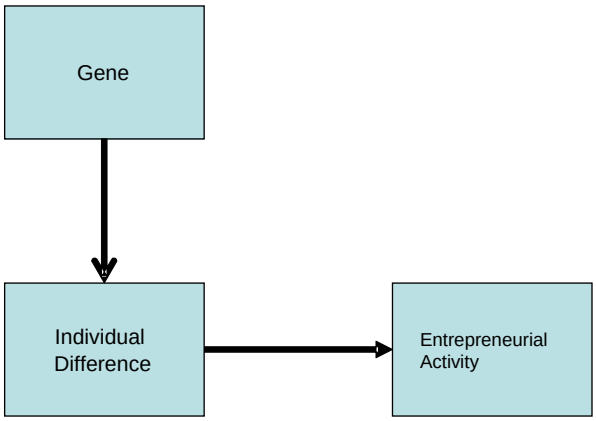


FIGURE 5
Gene-Environment Correlations

FIGURE 6
Pleiotropy

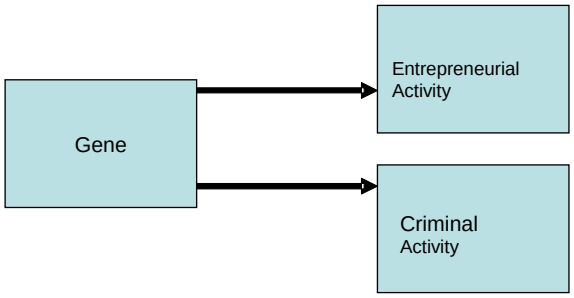


FIGURE 7
Epistasis

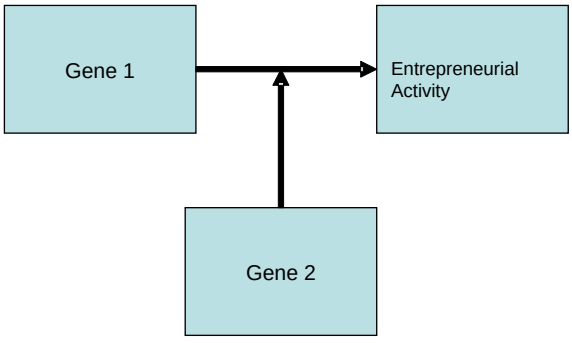
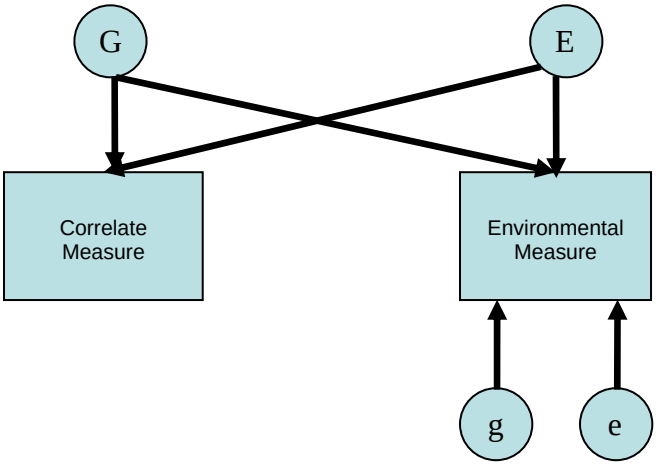


FIGURE 8
Multivariate Genetic Analysis



(Adapted from Plomin, 1994)

FIGURE 9:
Using Genetic Analysis in Research on Entrepreneurship