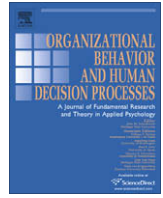




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Opportunity recognition and the tendency to be an entrepreneur: A bivariate genetics perspective

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ABSTRACT

We applied quantitative genetics techniques to a sample of 851 pairs of monozygotic and 855 pairs of dizygotic female twins to examine the influence of genetic factors on the variation across people in opportunity recognition. We also examined the extent to which the same genetic factors contribute to both opportunity recognition and the tendency to be an entrepreneur. We found substantial heritability for opportunity recognition (0.45), with no influence of the shared environment. Moreover, we found that 53% of the phenotypic correlation between opportunity recognition and the tendency to be an entrepreneur had a common genetic aetiology.

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Introduction

Whether it is to found an Internet search engine, an airline or a new restaurant, an important part of being an entrepreneur is identifying an opportunity for a new business, making opportunity recognition an important part of the entrepreneurship process. In the last decade, scholars have given increased attention to unravelling the antecedents of opportunity recognition (e.g. Baron & Ensley, 2006; Casson & Wadeson, 2007; Gaglio & Katz, 2001; Shane, 2000). One of the findings in this stream of research is that some people are better at noticing new business opportunities than other people, and that this superior ability makes them more likely than other people to start businesses (Baron & Ensley, 2006).

While researchers have identified some of the factors that account for the variation across people in opportunity recognition (Baron, 2007), to date researchers have not explored the question of whether some people are born with a greater genetic predisposition to identify entrepreneurial opportunities, and, if they are, whether the same genetic factors also account for the greater tendency of some people to start businesses. Moreover, previous research suggests that the genetic effects on the tendency to be an entrepreneur could be gender-specific, impacting women far more than men (Zhang et al., in press). In this paper, we provide the first empirical investigation of the genetic component of opportunity

recognition, and examine whether the covariance between opportunity recognition and the tendency of women to be entrepreneurs is partly accounted for by genetic factors.

Investigating the genetic aetiology of opportunity recognition and the tendency to be an entrepreneur among women is important for three reasons. First, an accurate understanding of entrepreneurship depends on the correctly ascribing the sources of variation between people in opportunity recognition. If the identification of new business opportunities is a necessary part of new business creation, then researchers must account for differences across people in their ability to recognize opportunities in order to explain new business formation. To date, researchers have explained only a small part of this variance (Butler, 2004; Shane, 2003). Understanding the role that genetics plays in opportunity recognition can help scholars build a more comprehensive and integrative understanding of this phenomenon.

This is true even if the genetic component to opportunity recognition, the tendency to be an entrepreneur, and other aspects of entrepreneurship are of the same magnitude as the genetic effects on psychological factors. No aspect of entrepreneurship is perfectly correlated with any psychological attribute, nor is there any theory that holds that people with certain personality traits *must* be entrepreneurs. Moreover, entrepreneurship is a different phenomenon from psychological characteristics. Therefore, the same genetic factors may influence psychological characteristics and the tendency to be an entrepreneur and opportunity recognition or they may not. Just as researchers cannot assume that leadership, job satisfaction, job preferences, and so on, have a genetic component because

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research shows that psychological characteristics have a genetic component, they cannot assume that entrepreneurship has a genetic component from evidence of a genetic effect on these other phenomena. In all cases, researchers must develop and test theory of the genetic effects on the particular phenomenon of interest.

Second, understanding the common genetic aetiology between opportunity recognition and the tendency to become an entrepreneur is important to suggest what, if any, interventions can be undertaken to encourage people to create new businesses. If the entire correlation between opportunity recognition and the tendency to be an entrepreneur is accounted for by genetic factors, this would suggest that we cannot influence the level of entrepreneurial exploitation that occurs in an economy by engaging in interventions that stimulate people to, or teach people to, recognize opportunities. On the other hand, if there are no shared genetic influences between opportunity recognition and the tendency to be an entrepreneur, then we could significantly affect new business creation by stimulating opportunity recognition.

Third, the factors influencing the tendency of women to become entrepreneurs may be different from those affecting their male counterparts. Research shows that the genetic effect on the tendency to be an entrepreneur may be stronger for women than for men (Zhang et al., *in press*). The differences between men and women in the strength of genetic effects on the tendency to be an entrepreneur suggests the importance of developing and testing gender-specific explanations for how genetics impacts different aspects of entrepreneurship.

Theory development

We propose that genetic factors influence the variation across people in opportunity recognition. We also propose that the same genetic factors that influence opportunity recognition also influence the tendency to be an entrepreneur. A common genetic aetiology for opportunity recognition and the tendency to be an entrepreneur would depend on three factors: First, that opportunity recognition is heritable; second, that the tendency to be an entrepreneur is heritable; and third, that a common genetic mechanism accounts for the heritability of both opportunity recognition and the tendency to be an entrepreneur. Below we offer the arguments for why these three conditions should be true.

The heritability of opportunity recognition

Opportunity recognition, or the identification of a chance to combine resources in a way that might generate a profit, is an important aspect of entrepreneurship (Gaglio & Katz, 2001; Shane, 2003; Shane & Venkataraman, 2000). Because people need to identify opportunities to be entrepreneurs, skill at opportunity identification increases the probability that a person will become an entrepreneur (Baron & Ensley, 2006; Casson & Wadeson, 2007; Gaglio & Katz, 2001; Shane, 2000). However, all people are not equally skilled at identifying entrepreneurial opportunities (Ardichvili, Cardozo, & Ray, 2003; Baron & Ensley, 2006). In fact, researchers have identified several differences between people that are correlated with opportunity recognition, including prior information (Shane, 2000), psychological “alertness” (Gaglio & Katz, 2001), pattern recognition skills (Baron & Ensley, 2006), and social network structure (Baron & Ozgen, 2007; Singh, Hills, Hybels, & Lumpkin, 1999).

While we know that a number of factors are correlated with being “good” at opportunity recognition (and that individual level variation in opportunity recognition is associated with being an entrepreneur), the origin of these interpersonal differences has not been completely identified. These differences might be learned,

or they might be the result of a person’s genetic endowment. Although both learning and genetics are likely explanations for individual level variation in opportunity recognition, this paper focuses on examining Ardichvili et al.’s conjecture (2003: 110) that “[t]hese individual differences may come from variations in individuals’ genetic makeup...”

The field of entrepreneurship does not yet have a fully articulated theory for how genetics influences differences across people in opportunity recognition, but it does have some plausible explanations. Below we examine four plausible mechanisms for these genetic effects.¹

First, genetics may affect people’s ability to identify opportunities by influencing their ability to creatively fashion business opportunities from bits of information. Shane (2000) explains that opportunities do not come in pre-packaged form. Rather, people need to combine information in novel ways to identify business opportunities. For instance, entrepreneurs might need to think of new ways to combine resources so that their value exceeds the cost of the resources themselves, or they might need to come up with novel solutions to customer problems (Ardichvili et al., 2003; Vesalainen & Pihkala, 1999). Whatever the specific information which entrepreneurs must use creatively, creativity is an important part of opportunity recognition. In fact, in a survey of entrepreneurs, Hills, Lumpkin, and Singh (1997) found that 90% believe that creativity is “very important” for opportunity recognition.

The importance of creativity to opportunity recognition suggests one way that genes influence opportunity recognition. Studies show that 55% of the difference between people in creativity is genetic (Bouchard, McGue, Hur, & Horn, 1998), with two genes – DRD2 and TPH1 – having been found to account for 9% of the difference between people in creativity (Reuter, Roth, Holve, & Hennig, 2006). Thus, genes might facilitate opportunity recognition by making some people more creative than others.

Second, genetics may influence people’s ability to identify entrepreneurial opportunity by affecting their openness to experience. Openness to experience enhances opportunity recognition because new experiences provide novel information, and facilitate mental processes, that are helpful to identifying opportunities (Zhao & Seibert, 2006).

Genetics affects openness to experience, accounting for between 45% and 61% of people’s differences in this personality trait (Bouchard & Loehlin, 2001; Loehlin, 1992). Moreover, researchers have found that individuals with certain variants of the DRD4 gene are more open to experience than those with different versions of the genes (Comings et al., 1999). Thus, genes might facilitate opportunity recognition by making some people more open to experience than others.

Third, genetics may affect people’s ability to recognize entrepreneurial opportunities by facilitating the formation of strong social networks. Social ties facilitate opportunity recognition because other people often provide entrepreneurs with information helpful to the process (Ardichvili et al., 2003). Moreover, the necessary information to identify opportunities is often distributed across a number of sources, making broad social ties useful to accessing all of the needed bits of information (Johansson, 2000).

Research shows that strong social ties enhance opportunity recognition. Koller found that 46% of firm founders had their business idea suggested to them by someone with whom they had a social tie. Hills et al. (1997) found that entrepreneurs who have broader social networks recognize more opportunities than those with

¹ We focus on these four mechanisms because they could also account for a common genetic aetiology between opportunity recognition and the tendency to be an entrepreneur. Genetic factors could influence opportunity recognition through other mechanisms as well.

narrower social networks. Baron and Ozgen (2007) found that entrepreneurs with more ties to mentors, other industry participants and members of trade associations, the better they were at recognizing opportunities. And Singh et al. (1999) showed that entrepreneurs with more diverse social ties were more likely to identify entrepreneurial opportunities than those with less diverse ties.

The strength of a person's social network is, in part, genetic. Researchers have found that a person's choice of friends, number of friends and confidants, frequency of interaction with friends, amount of social support from friends, social network denseness, network centrality, social relationship intensity, sociability, social avoidance, and social skills, are all affected by genetics (Bouchard et al., 1998; Carey, 2003; Fowler, Dawes, & Christakis, 2009; Iervolino et al., 2002; Jang, Livesley, Vernon, & Jackson, 1996; Loehlin & Gough, 1990; Manke, McGuire, Reiss, Hetherington, & Plomin, 1995; Plomin, 1994; Schnittker, 2008). Thus, genes might facilitate opportunity recognition by giving some people better social networks than others.

Fourth, genetics may influence opportunity recognition by affecting preferences for autonomy and job security. People with a higher predisposition for autonomy and a lower predisposition for job security are more interested in working for themselves, and thus are more likely to search for entrepreneurial opportunities than other people (Shane, 2003).

The preference for both autonomy and job security are partially genetic. Studies show that genes account for about a third of the difference between people in both preferences (Arvey, Bouchard, Segal, & Abraham, 1989). Thus, genes might facilitate opportunity recognition by making some people more interested in autonomy and less interested in job security than others.

These arguments lead to the following hypothesis:

Hypothesis 1. Genetic factors influence part of the variation across people in opportunity recognition.

The heritability of entrepreneurship

Whether entrepreneurship is measured as self-employment, starting companies, owning one's own business, or being involved in the firm start-up process, recent research shows that the tendency to be an entrepreneur is partially genetic, with heritabilities from 37% to 48%, depending on the measure. Moreover, these heritabilities are present even after taking into consideration the effects of age, income, education, marital status, race, and immigrant status (Nicolaou, Shane, Cherkas, Hunkin, & Spector, 2008).

The genetic effect on the tendency to be an entrepreneur may also be much stronger for women than for men. Prior research shows substantially higher heritabilities of entrepreneurship for women than for men (Zhang et al., *in press*). Researchers have speculated that genetic effects may be more powerful for women because there is a lower prevalence of entrepreneurship for women than for men (Brush, 1992). As a result, the situational factors that motivate men to start businesses may not have as large an effect on women. For instance, men might be more likely to start a company in response to the experience of working in a small business, while this experience might not trigger entrepreneurial tendencies in women. The end result is little genetic effect on the tendency of men to become entrepreneurs, but a strong genetic effect on women (Shane, *forthcoming*).

Common genetic factors influencing opportunity recognition and the tendency to be an entrepreneur

The same genetic factors that influence the tendency to be an entrepreneur might also influence opportunity recognition. Much

research shows that similar factors are associated with both phenomena (Baron, 2007). Moreover, all of the above-mentioned mechanisms, through which genetics affects opportunity recognition, also affect the tendency to be an entrepreneur.

First, creativity affects the tendency to be an entrepreneur. Creativity is necessary not just to identify business opportunities, but also to figure out how to obtain resources to pursue them. Moreover, over time, the conditions facing businesses change and entrepreneurs need to come up with creative responses to those changes (Shane, 2003).

Empirical research confirms this proposition, showing that entrepreneurs are more creative than non-entrepreneurs. Hull, Bosley, and Udell (1982) found that business owners scored higher on a measure of creativity than non-owners, while Caird (1991) and Cromie and O'Donoghue (1992) found that firm owners were more creative than the general population.

Second, openness to experience affects the tendency to be an entrepreneur. Openness to experience provides people with a variety of information that helps them to develop new products and organizations. Moreover, it provides them with an understanding of a wide range of customers and customer attitudes that is useful in running a business (Shane, 2003). Empirically, a recent meta-analysis confirms that entrepreneurs are more open to experience than managers (Zhao & Seibert, 2006).

Third, social network strength affects the tendency to be an entrepreneur (Hills et al., 1997; Singh et al., 1999; Baron and Ozgen, 2007; Aldrich & Kim, 2007). Entrepreneurs use their social networks to obtain financial and human resources (Aldrich, 1999) because social relationships facilitate resource acquisition under conditions of uncertainty and information asymmetry (Shane, 2003). Moreover, social networks provide entrepreneurs with useful information about many aspects of running their businesses, from government regulation to interactions with suppliers (Cromie & Birley, 1993).

Empirical research shows that entrepreneurs tend to have stronger social networks than other people. For instance, Aldrich, Rosen, and Woodward (1987) found that people who have more contact with other members of their social networks are more likely to start businesses. Denison, Swaminathan, and Rothbard (1994) found that the size of a person's social network had a positive effect on their probability of starting a business. Shane and Cable (2002) and Shane and Stuart (2002) found that the presence of social ties between entrepreneurs and investors increased the odds that the entrepreneurs would raise money from the investors.

Fourth, the desire for autonomy and the preference for job security affect the tendency to be an entrepreneur. People high in need for autonomy have a disproportionate tendency to start businesses because they want to set their own rules and hours, pick their own goals and plans, and make their own decisions (Rauch & Frese, 2007a, 2007b).

Empirical studies show that entrepreneurs are higher in the desire for autonomy and lower in preference for job security than other people (Caird, 1991; Cromie & O'Donoghue, 1992; Hornaday & Aboud, 1973). In fact, one study showed that agreement with the statement: "being my own boss is vital in choosing a job" increases the odds that a person will be self-employed ten years later, while agreement with the statement: "job security is most vital in choosing a job" reduces the odds that a person will be self-employed a decade hence (Burke, FitzRoy, & Nolan, 2000). Moreover, Vesalainen and Pihkala (1999) found that the desire for independence increases the odds that a person will engage in the business start-up process. And Reynolds and White (1997) found that people engaged in the start-up process scored higher on measures of autonomy and independence than a control group representing the overall population.

In short, we argue that the same genetically-influenced factors increase the probability that people will both recognize opportunities and be entrepreneurs. Therefore, we hypothesize:

Hypothesis 2. The same genetic factors account for part of the covariation between opportunity recognition and the tendency to be an entrepreneur.

Methodology

We use behavioral genetics techniques to examine the degree to which opportunity recognition has a genetic component, and whether the same genetic component accounts for variation across people in both opportunity recognition and the tendency to be an entrepreneur. Behavioral genetics involves the comparison of monozygotic (MZ) and dizygotic (DZ) twins to disentangle the portion of the variance in opportunity recognition that comes from genetic and environmental factors as well as the portion of the covariance between opportunity recognition and the tendency to be an entrepreneur that is accounted for by genetic factors. MZ twins are formed when a single sperm fertilizes a single egg; the egg subsequently splits into two, resulting into two individuals who are genetically identical (Kendler & Prescott, 2006). DZ twins are formed when two different eggs are fertilized by two different sperm, and hence share, on average, 50% of their segregating genes, just like all other full siblings.

Because MZ twins share their entire genetic composition and DZ twins share, on average, 50% of their segregating genes, studies of twins can provide estimates in the heritability (or degree to which the source of variation in a population is genetic) of a phenotype of interest (in this case, opportunity recognition). Assuming that MZ and DZ co-twins do not differ in the similarity of their environments, differences in the correlations between pairs of MZ and DZ co-twins is a function of genetic factors.

We use bivariate genetics techniques to identify whether the same genetic factors influence both opportunity recognition and the tendency to be an entrepreneur. By comparing MZ and DZ twin correlations across both opportunity recognition and the tendency to be an entrepreneur, (e.g., we compare one twin's opportunity recognition score with its co-twin's tendency to be an entrepreneur score) we can determine the extent to which the correlation between opportunity recognition and the tendency to be an entrepreneur is a function of genetic factors. If the cross-trait-cross-twin correlations are greater for MZ twins than for DZ twins, then genetic factors contribute to the phenotypic correlation between these two variables, but if the cross-trait-cross-twin correlations are equal for MZ and DZ twins, or are greater for DZ twins than for MZ twins, then genetic factors do not contribute to the phenotypic correlation between these two variables.

The validity of twin studies rests on the assumption that the shared environment of DZ twins is similar to that of the MZ twins, so called the equal environments assumption (EEA). For this assumption to be violated environmental factors must treat MZ twins in a different way than DZ twins and this difference in treatment must influence the phenotype under study. Different methods have been used to evaluate the EEA, all of which confirm the robustness of the assumption (Kendler & Prescott, 2006). First, studies have compared the phenotypic similarity in twin pairs using data on real and perceived zygosity, and have found that actual, and not perceived, twin zygosity is what influences twin similarity (Kendler & Prescott, 2006; Scarr, 1968; Scarr & Carter-Saltzman, 1979). Second, studies that have used different methods to assess the similarity of environmental exposure, such as (i) twin ratings of similarity at childhood, adolescence and adulthood, (ii) ratings of physical similarity from photographs, and (iii) ratings

of similarity of parental treatment, have failed to find consistent violations of the EEA (Hettema, Neale, & Kendler, 1995; Kendler, Neale, Kessler, Heath, & Eaves, 1994; Kendler & Prescott, 2006).

The frequency of contact between MZ and DZ twins constitutes another dimension of the equal environments assumption (EEA) (Mitchell et al., 2007). If MZ twins interact more often than DZ twins, greater similarity in their behavior might be accounted for by frequency of contact rather than genetic factors. For this greater contact between MZ than DZ twins to violate the EEA two conditions must hold. First, MZ co-twins must be in greater contact than DZ co-twins. Second, and more importantly, the *direction of causality* must run from frequency of contact to twin similarity. If greater contact between MZ twins cause greater MZ twin similarity, then the equal environments assumption will be violated and heritability parameters will be overestimated. However, if greater MZ twin similarity causes more MZ twin contact then the equal environments assumption remains valid and the heritability parameters remain unaffected (Posner, Baker, Heath, & Martin, 1996). The evidence on this matter gathered by previous researchers suggests that the direction of causality runs from similarity to contact rather than the other way round (Lykken, McGue, Bouchard, & Tellegen, 1990; Posner et al., 1996), preserving the robustness of the equal environments assumption.

Sample

Our sample consists of 3,412 twins, comprising 851 pairs of MZ and 855 pairs of DZ female twins from the United Kingdom who were raised together. We ascertained twin zygosity through a standardized validated questionnaire – which has an accuracy of 95% (Martin & Martin, 1975; Peeters, Gestel, Vlietinck, Derom, & Derom, 1998) – and, in cases of uncertainty, through multiplex DNA fingerprinting using variable tandem repeats – which has an accuracy of around 99.7% (Singer, MacGregor, Cherkas, & Spector, 2005).

The twins were initially recruited through a national media campaign designed to gather data for medical research (Spector, Cicuttini, Baker, Loughlin, & Hart, 1996; www.twinsuk.ac.uk). In 2006, each subject was sent a self-completion postal questionnaire, which focused mostly on gathering information on medical conditions (e.g. osteoporosis, response to pain etc.), but which also gathered information relevant to the present study. Because the focus of the data collection was on medical issues, the subjects were unaware of the hypotheses of this study when completing the questionnaire. The average age of the twins was 55 years (standard deviation = 12.88).

Measure of opportunity recognition

We measure opportunity recognition through the use of a five-item scale composed of the following questions drawn from the literature on opportunity recognition (Baron & Ozgen, 2007; Singh et al., 1999): (In all five opportunity recognition questions we used a five point scale from one to five. In four of these questions the answer categories ranged from “strongly disagree” to “strongly agree”. With the third question the answer categories were “none”, “one”, “two”, “three”, “four or more”, the respective answers were coded from one to five.)

- I enjoy thinking about new ways of doing things.
- I frequently identify opportunities to start-up new businesses (even though I may not pursue them).
- How many ideas for new businesses did you think of in the past month?

- I frequently identify ideas that can be converted into new products or services (even though I may not pursue them).
- I generally lack ideas that may materialise into profitable enterprises (reverse scored).

This scale has a Cronbach's alpha of 0.72, indicating that it is reliable.

Measures of the tendency to be an entrepreneur

The literature does not agree on a definition of entrepreneurship – the definitions used by researchers range from self-employment (Parker, 2004) to founding a new firm (Gartner, 1988) to being an owner-operator of a company (Hull et al., 1982). Rather than choose one definition over another, we sought to determine whether these different definitions measure the same underlying construct, and, if so, to create an overall measure of the tendency to be an entrepreneur that is based on these different variables.

We asked the respondents about the following dimensions of the tendency to be an entrepreneur:

- Self-employment, (Amit, Muller, & Cockburn, 1995; Burke et al., 2000; Evans & Leighton, 1989; Parker, 2004; Taylor, 1996; Van Praag & Cramer, 2001; Sorenson, 2007), which we operationalize with the question: “in your working life, how long have you been self-employed?”
- Starting a new business (Choi & Shepherd, 2004; Delmar & Davidsson, 2000; Gartner, 1988), which we operationalize with the question: “in your working life, how many new businesses have you started?”
- Being an owner-operator of a company (Ahmed, 1985; Bitler, Moskowitz, & Vissing-Jørgensen, 2005; Hull et al., 1982), which we operationalize with the question: “in your working life, how many companies have you been an owner-operator of?”
- Engaging in the firm start-up process (Choi & Shepherd, 2004; Delmar & Shane, 2003; Reynolds, Carter, Gartner, & Greene, 2004; Ruef, Aldrich, & Carter, 2003), which we operationalize with the question: “in your working life, for how many new business ideas have you taken any actions toward the creation of a new business?”

We factor analyzed the responses and found that they loaded on the same factor. We then combined these different items into a scale, which we found to be reliable, it had a Cronbach's alpha of 0.79.²

Structural equation modeling

The relative contribution of genetic and environmental variation to opportunity recognition can be estimate quantitatively by using variance components analysis. In the basic twin design, variation can arise from three sources: additive genetic effects (A), shared (or common) environmental effects (C) (i.e. factors shared by family members), and non-shared environmental factors (E) (i.e., environmental effects that are unique to an individual) (Kendler & Prescott, 2006).

Diagrammatically the model that we estimate is shown in Fig. 1. The boxes represent the observed variables (i.e. opportunity recognition or the tendency to be an entrepreneur), while the circles

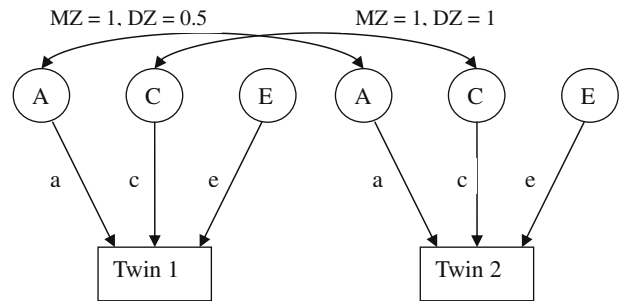


Fig. 1. Path diagram for opportunity recognition.

represent the latent factors that the model estimates (i.e., additive genetic (A), common environmental (C) and non-shared environmental factors (E)). The correlation between the latent additive genetic factors is constrained at 1.00 for MZ and at 0.5 for DZ twins to reflect the degree of genetic relatedness. Because both MZ and DZ twin pairs were raised together, and so shared the same common environment, the correlation between latent common environmental factors is constrained at 1.00 for both types of twins. The non-shared environmental components are assumed to be uncorrelated across members of a twin pair.

The contributions of A, C, and E to the total variance are evaluated through a series of nested sub-model comparisons using the MX model fitting software. The fit of each model is estimated using a chi-square goodness of fit test, with a perfect fit denoted by 1.00. A non-significant chi-square indicates a good model fit. We used the Akaike Information Criterion (AIC) (Akaike, 1987) and the Root Mean Square Error of Approximation (RMSEA) to select the best fitting model (Neale & Maes, 2002). (Lower values of the AIC and the RMSEA indicate a better model fit.)

Bivariate genetic analysis

The degree to which the same genetic factors affect both opportunity recognition and the tendency to be an entrepreneur is measured through bivariate genetic analysis (the path diagram is illustrated in Fig. 2). Bivariate genetic analysis allows the covariance between opportunity recognition and the tendency to be an entrepreneur to be partitioned into that due to additive genetic, shared environmental, and non-shared environmental effects (Kuntsi et al., 2004; Rice, van den Bree, & Thapar, 2004; Singer et al., 2005). In such analysis, MZ and DZ twin correlations are compared across variables. In our case, one twin's score on opportunity recognition is correlated with the co-twin's score on the tendency to be an entrepreneur. If the cross-trait cross-twin correlations are greater for MZ twins than for DZ twins, this means that genetic factors contribute to the phenotypic correlation between the two variables. The bivariate model is based on a Cholesky parameterization (Kuntsi et al., 2004; Loehlin, 1996).

In this figure r_A , r_C , and r_E represent the genetic correlation, the shared environmental correlation and the unique environmental correlation, respectively. The genetic correlation, r_A , indicates the extent to which the genetic influences on recognition overlap with those on the tendency to be an entrepreneur, irrespective of their individual heritabilities (Kuntsi et al., 2004). A genetic correlation of 1 would mean that all genetic influences on opportunity recognition also impact the tendency to be an entrepreneur (Plomin, DeFries, McClearn, & McGuffin, 2001).

Results

The descriptive statistics and correlations are shown in Table 1. There were no statistically significant differences between MZ and

² A factor analysis with Varimax rotation of the four tendency to be an entrepreneur and the five opportunity recognition questions yielded two distinct factors with eigenvalues were 3.52 and 1.67 respectively. The KMO measure of sampling adequacy was 0.82 and Bartlett's test of Sphericity was highly significant ($p = .0001$; $\chi^2 = 4316$; 36 *df*). There were no cross factor loadings and all loadings were higher than 0.50.

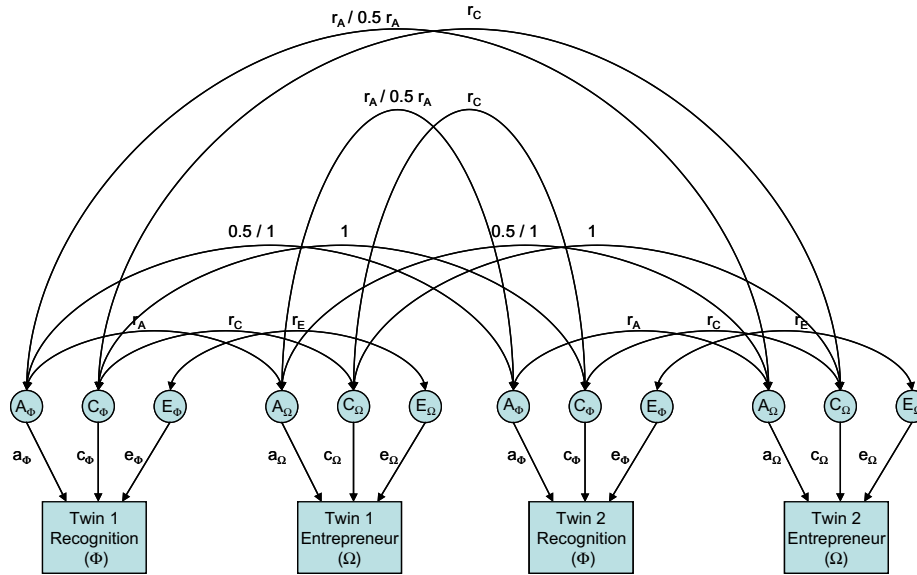


Fig. 2. Path diagram for opportunity recognition and the tendency to be an entrepreneur.

Table 1
Descriptive statistics and correlations.

Variable	μ	σ	1	2	3	4	5	6	7	8
1. Opportunity recognition scale	1.37	0.82								
2. Age	55.6	12.9	-.18							
3. Religion	.10	.30	.05	-.10						
4. Children	.73	.44	-.04	.30	-.05					
5. Businesses started	.34	.75	.34	.03	.05	.04				
6. Companies owned and operated	.23	.64	.22	.00	.02	.02	.65			
7. Years self-employed	.65	1.30	.21	.09	.04	.07	.59	.50		
8. Start-up efforts	.44	.91	.41	.01	.02	.03	.69	.49	.43	
9. Entrepreneurship scale	.41	.73	.35	.05	.04	.05	.87	.76	.84	.78

DZ twins on measures of opportunity recognition and the tendency to be an entrepreneur.

Table 2 shows the cross-twin MZ and DZ correlations and the cross-twin-cross-trait correlations for each variable. The values in bold are the MZ and DZ cross-twin correlations for each variable. The MZ and DZ cross-twin correlations for opportunity recognition are 0.46 and 0.23 respectively, while the equivalent correlations for the tendency to be an entrepreneur are 0.31 and 0.15.

Table 2
Cross-trait cross-twin correlations for the opportunity recognition and entrepreneurship scales.

	Twin 1 opportunity recognition	Twin 1 entrepreneurship	Twin 2 opportunity recognition	Twin 2 entrepreneurship
<i>MZ twins</i>				
Twin 1 opportunity recognition	1			
Twin 1 entrepreneurship	.36	1		
Twin 2 opportunity recognition	.46	.24	1	
Twin 2 entrepreneurship	.16	.31	.35	1
<i>DZ twins</i>				
Twin 1 opportunity recognition	1			
Twin 1 entrepreneurship	.32	1		
Twin 2 opportunity recognition	.23	.08	1	
Twin 2 entrepreneurship	.10	.15	.38	1

Table 3 shows the results of Twin model fitting for opportunity recognition. The chi-square test for goodness of fit for the model, the Akaike Information Criterion (Akaike, 1987) and the Root Mean Square Error of Approximation (RMSEA) showed that the best fitting model for opportunity recognition included additive genetic and non-shared environmental factors (AE model). The heritability of the opportunity recognition scale was 0.45 ($p = .21$; AIC = -2.20; RMSEA = 0.03) [95% CI 0.39–0.50%]. None of the variance could be attributed to shared environmental factors.

Table 4 shows the results of model fitting to the tendency to be an entrepreneur. The AE was the best fitting model, with 30% of the variance in tendency to be an entrepreneur explained by genetic factors ($p = .53$; AIC = -4.85; RMSEA = .01) [95% CI 0.24–0.36%]. Moreover, the genetic effect was not an artefact of the scale used to measure the tendency to be an entrepreneur. The AE was the best fitting model for each of the measures of entrepreneurship alone, with 40% of the variance in the “start a new business” measure explained by genetic factors ($p = .10$; AIC = -0.07; RMSEA = 0.02) [95% CI 0.29–0.51%]; 39% of the variance in the “self-employment” measure ($p = .81$; AIC = -6.40; RMSEA = 0.001) [95% CI 0.28–0.49%]; 43% of the variance in the “engage in the firm start-up process” measure ($p = .67$; AIC = -5.66; RMSEA = 0.001) [95% CI 0.33–0.53%]; 30% of the variance in the “owner-operator of a company” measure ($p = .96$; AIC = -7.39; RMSEA = 0.001) [95% CI 0.17–0.43%]; and 31% of the variance in an “opportunity exploitation” scale (Choi & Shepherd, 2004) composed of the “starting a new business” and “engaging in the firm start-up process” measures ($p = .54$; AIC = -4.88; RMSEA = 0.001) [95% CI 0.25–0.37%].

Table 3
Heritability estimates for the opportunity recognition scale.

Model	A (95% CI)	C (95% CI)	E (95% CI)	χ^2	df	p Value	AIC	RMSEA
ACE	0.45 (0.35–0.50)	0 (0–0.08)	0.55 (0.50–0.61)	5.81	3	.12	–0.20	0.036
CE	–	0.33 (0.28–0.37)	0.67 (0.63–0.72)	42.79	4	.001	37.79	0.119
AE	0.45 (0.39–0.50)	–	0.55 (0.50–0.61)	5.81	4	.21	–2.20	0.025

Note: A, additive genetic; C, common environment; E, unique environment.

Table 4
Heritability estimates for the entrepreneurship scale.

Model	A (95% CI)	C (95% CI)	E (95% CI)	χ^2	df	p Value	AIC	RMSEA
ACE	0.30 (0.14–0.36)	0 (0–0.14)	0.70 (0.64–0.76)	3.15	3	.37	–2.84	0.007
CE	–	0.23 (0.18–0.28)	0.77 (0.72–0.82)	14.34	4	.01	6.34	0.061
AE	0.30 (0.24–0.36)	–	0.70 (0.64–0.76)	3.15	4	.53	–4.85	0.001

Note: A, additive genetic; C, common environment; E, unique environment.

Table 5
Bivariate genetic analysis between opportunity recognition and the tendency to be an entrepreneur.

AE Model	r_A (95% CI)	r_E (95% CI)	r_C	Phenotypic correlation	% of phenotypic r attributable to genetic influence (95% CI)
Recognition-entrepreneurship	.51 (.40–.63)	.26 (.20–.32)	0	0.35	0.53 (0.42–0.66)
AIC = –9.00; p = .16; RMSEA = 0.01					

None of the variance in the tendency to be an entrepreneur could be attributed to shared environmental factors.

The underlined values in Table 2 show the cross-twin-cross-trait correlations for each variable. The cross-trait cross-twin correlations for MZ twins were 0.16 and 0.24. Similarly, the cross-trait cross-twin correlations for DZ twins were 0.10 and 0.08. The cross-trait cross-twin correlations are greater for MZ twins than for DZ twins suggesting that genetic factors are contributing to the phenotypic correlation between opportunity recognition and the tendency to be an entrepreneur. In fact, the bivariate genetic analysis indicates that 53%³ of the phenotypic correlation between the tendency to be an entrepreneur and opportunity recognition is accounted for by genetic influences that are common to the two (see Table 5).

As a robustness check we also calculated bivariate models using the specific items that compose the entrepreneurship scale – self-employment, starting a business, engaged in the firm start-up process, and being an owner-operator of a company – to ensure that the results reported in Table 5 are not an artefact of scale construction. The proportion of the phenotypic correlation accounted for by genetic factors is similar for the specific items composing the entrepreneurship scale and the overall scale, indicating that the findings described in Table 5 are not an artefact.

Discussion

We applied quantitative genetics techniques to a female sample of 851 pairs of MZ twins and 855 pairs of DZ twins to examine the magnitude of the genetic component of opportunity recognition and the extent to which the same genetic factors explain both opportunity recognition and the tendency to be an entrepreneur.

³ Table 5 shows that the genetic correlation (r_A) is 0.51. Multiplying the genetic correlation by the square root of the univariate heritability estimates for recognition and exploitation yields the amount of the correlation between recognition and exploitation that is explained by genetic factors, i.e. $0.51 \times \sqrt{0.45} \times \sqrt{0.30} = 0.187$. This means that 53% of the phenotypic correlation between exploitation and recognition (which is 0.35) is accounted for by genetic influences that are common to exploitation and recognition ($0.187/0.35 = 0.53$).

The results showed substantial heritability for opportunity recognition (0.45), with no influence of the shared environment. We found that 53% of the phenotypic correlation between opportunity recognition and the tendency to be an entrepreneur had a common genetic aetiology.

Limitations

Like all studies, this one is not without limitations. Our study’s validity depends on support for the equal environments assumption. This assumption holds that MZ twins are not treated more similarly than DZ twins with respect to the phenotype under study, and, in our case would be violated if the family or non-family environment treated MZ twins more similarly than DZ twins with respect to opportunity recognition and the tendency to be an entrepreneur. For example, if loan officers were more likely to offer the same loan terms to pairs of MZ twins than to pairs of DZ twins, the equal environments assumption would be violated. Alternatively, if other people provide MZ twins with more similar information about entrepreneurial opportunities than they provide DZ twins, the equal environments assumption would be violated.

However, we have no way of verifying the validity of the assumption for either opportunity recognition or the tendency to be an entrepreneur. While we know of no evidence, anecdotal or statistical, which suggests that the environment treats MZ twins more similarly than DZ twins with respect to opportunity recognition or the tendency to be an entrepreneur and therefore believe that the assumption holds, we acknowledge that our inability to “show” support for the assumption is a limitation of the paper.

Our results also have limited generalizability. Because our sample was initially recruited to study medical conditions that occur primarily in women, the sample is entirely female, limiting our ability to generalize to men. In fact, researchers have reason to believe that the effect of genetic factors on entrepreneurial behavior is gender-specific. Therefore, we cannot assume that the same patterns we found in this study exist for men.

Our results are only a first step toward explaining how our genes influence entrepreneurial behavior. Behavioral genetics

studies, such as this one, cannot identify the specific genes that affect the likelihood of opportunity recognition and the tendency to be an entrepreneur. Therefore, we know that some of the same genes affect both aspects of entrepreneurial behavior, given the relatively high genetic correlation between opportunity recognition and the tendency to be an entrepreneur. However, we must await future research to identify what those genes are; how many are at work; how they interact; and the mechanisms through which they operate.

Implications

Despite the limitations just mentioned, the results of our study have implications for both research on, and the practice of, entrepreneurship. On the research side, our study contributes to an emerging stream of research that integrates biological and sociological explanations for entrepreneurial activity (White, Thornhill, & Hampson, 2006; Nicolaou, Shane, Cherkas, Hunkin, & Spector, 2008). While this school of thought does not negate the importance of environmental factors in explaining entrepreneurship, it suggests that we need to consider also the influence of biological factors if we are to develop accurate explanations for this important phenomenon.

Our study suggests the value of considering the role of genetics in the opportunity recognition process, particularly when examining female entrepreneurs and prospective entrepreneurs. To date, research has explained only a small part of the variance between people in the recognition of new business opportunities (Ardichvili et al., 2003; Baron & Ensley, 2006; Gaglio & Katz, 2001; Shane, 2000; Singh et al., 1999; Baron & Ozgen, 2007). Moreover, much of the research has only identified proximal factors that are correlated with opportunity recognition, not the underlying mechanisms through which this process works. Whether the underlying mechanisms that account for these correlations involve learning or genetics (we believe that they are most likely a combination of both), has important ramifications for how we think about the answers to the questions of “why” and “how” people identify new business opportunities. Our results indicate that researchers should view opportunity recognition as an activity for which our genetic make-up plays a role in explaining the variance across people in this activity. While future empirical work corroborating our findings would be necessary before firmly drawing any conclusions, this pattern suggests a different way of thinking about why and how people recognize entrepreneurial opportunities.

It is important to stress that our results do not imply that opportunity recognition is genetically determined, but only that genetic factors influence the propensity to recognize opportunities. In fact, our results show that a substantial part of opportunity recognition is accounted for by non-shared environmental factors (plus measurement error). Nevertheless, our finding that the variance across people in opportunity recognition is a function of both genetic and environmental factors suggests that the implicit “all environmental” approach in the literature is incomplete.

The influence of genetic factors on opportunity recognition also implies that the use of non-experimental data to investigate the impact of environmental factors can lead to confounded estimates because unobserved genetic endowments simultaneously influence both the environmental factors correlated with opportunity recognition and opportunity recognition itself (Kohler, Behrman, & Skytthe, 2005). Therefore, our results indicate that scholars need to use fixed-effects models within MZ twins (co-twin control designs) to overcome the estimation problems caused by the effects of genetic factors on the environmental factors themselves (Kohler et al., 2005). Such approaches will enable entrepreneurship researchers to conduct more rigorous empirical analyses of the

relationship between environmental variables and the likelihood of recognizing entrepreneurial opportunities.

Our finding that the “shared environment” did not influence opportunity recognition was quite surprising. Nevertheless, this is consistent with research in other areas of quantitative genetics that found no influence of the shared environment in many aspects of human behavior (e.g. Kendler & Prescott, 2006; Plomin et al., 2001; Singer et al., 2006). For example, personality characteristics and psychopathology also show zero shared environmental influences (Kendler & Prescott, 2006; Loehlin, 1992; Plomin, DeFries, McClearn, & McGuffin, 2008). Our finding of no effect of the shared environment implies that “shared environmental” influences such as a person’s upbringing are not important in opportunity recognition.⁴

Our finding of a common genetic factor for both opportunity recognition and the tendency to be an entrepreneur indicates that these two activities are fundamentally linked. However, we do not argue that genetic factors *cause* opportunity recognition to increase, which, in turn, *causes* people to become entrepreneurs. Opportunity recognition might increase the likelihood that a person becomes an entrepreneur, but being an entrepreneur may also make people more alert to entrepreneurial opportunities. Our results merely show that the same genetic factors influence the tendency to both recognize opportunities and be an entrepreneur and would be consistent with either or both directions of causality between opportunity recognition and the tendency to be an entrepreneur.

Nevertheless, the bivariate genetic association that we found between opportunity recognition and the tendency to be an entrepreneur has implications for molecular genetics research. It implies that if specific genes were found to account for some of the variance in opportunity recognition, these same genes would be good candidates to consider for explaining some of the variance in the tendency to be an entrepreneur. However, half of the genetic variance in the tendency to be an entrepreneur is not shared with recognition, suggesting that independent genetic effects on the tendency to be an entrepreneur exist as well.

Finally, our study has implications for research on gender differences in entrepreneurship. Many researchers have argued that explanations for why and how people become entrepreneurs should be gender-specific (Shane, 2003). Recent research shows that genetic factors may play a larger role in explaining whether or not women become entrepreneurs than they do in explaining whether or not men do. Our results support this stream of research, showing that the same genetic factors that influence the tendency of women to become entrepreneurs also play a large role in opportunity recognition by women.

Our findings also have implications for research on organizations in general. Researchers interested in organizations and orga-

⁴ It is important to clarify what this finding actually means. It means that each child has a unique and specific upbringing, and this is modelled through the “non-shared environmental factor” (Arvey Rotundo, Johnson, Zhang, & McGue, 2006). It also “implies that sharing a family environment does not contribute importantly to family resemblance. It does *not* mean that the... family environment is unimportant (Plomin et al., 2008, p. 73; emphasis added)” or that families and peers do not influence the likelihood of engaging in entrepreneurship. Rather, “if these factors are important, they are not affecting the two members of a twin pair in the same way” (Kendler & Prescott, 2006, p. 345). As Kendler and Prescott (2006, p. 344) explain, “In twin studies we detect the effects of family environment only if they effectively influence both twins to a similar degree. If parents are abusive to one twin in a way that has a strong impact on later risk for psychopathology but are not abusive to the other twin, it might seem logical that this effect – which certainly occurs within the family – would be identified in a twin analysis as part of the “family environment”. But it will not be. Instead, it will appear as an individual-specific effect because it affects only one member of the twin pair. Alternatively, the twins might be exposed to the same adversity but, because of prior differences in experience... one twin may be more vulnerable to its pathogenic effects than the other. Again, in a twin design this will appear as an individual-specific, not a shared environmental effect.”

nizational behavior cannot simply assume the existence of those organizations, but also need to understand their creation. Because new organizations are created by entrepreneurs and entrepreneurs decisions are affected by their psychological processes, any research which provides insight into how the psychological processes of entrepreneurs affect their decision making should be of interest to organization scholars.

One of the most fundamental questions about human decision making and the psychological processes underlying it is whether the driving forces behind these activities is nature or nurture. Our study examines the extent to which the psychological processes and human decision making that underlies entrepreneurial efforts to create organizations is partly innate. Our findings that opportunity recognition is partially genetic and that the same genetic factors influence both opportunity recognition and the decision to be an entrepreneur provides important insight into the source of factors affecting the creation of new organizations, which is necessary for the development of accurate theories of organization.

Our study also has important implications for business practice. Our finding that the entire *environmental influence* on opportunity recognition was accounted for by *unique* environmental factors should hearten managers and policy makers. Given that a significant component of the unique environment comes from a person's work environment, our results suggest that companies and policy makers can influence the likelihood that people will recognize entrepreneurial opportunities. Thus, efforts to find the right environmental influences to enhance opportunity recognition – be those training, working conditions, or incentives – may prove to be quite fruitful.

However, our finding that 53% of the phenotypic correlation between opportunity recognition and the tendency to be an entrepreneur is accounted for by the same genetic factor indicates that our ability to encourage entrepreneurial activity through interventions designed to influence their ability to recognize new business opportunities is smaller than many observers currently believe. From a practical point of view, this constraint suggests a relatively smaller role for interventions to enhance opportunity recognition as a way to influence the level of entrepreneurship that occurs.

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