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Entrepreneurs and evolutionary biology: The relationship between testosterone and new venture creation

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Abstract

Biological evolutionary processes select for heritable behaviors providing a survival and reproductive advantage. Accordingly, how we behave is, at least in part, affected by the evolutionary history of our species. This research uses evolutionary psychology as the theoretical perspective for exploring the relationship between a heritable biological characteristic (testosterone level) and an important business behavior (new venture creation). Data were collected from 31 MBA students with significant prior involvement in new venture creation and from 79 other student subjects with no new venture start-up experience. Consistent with evolutionary psychological theory, the biological (testosterone level) effect upon behavior (new venture creation) is partially mediated by the psychological (risk propensity).

Keywords: Entrepreneurship; Evolution; Biology; Risk-taking; Testosterone

Introduction

This paper explores the relationship between a biological characteristic of individuals, their testosterone level, and entrepreneurial behavior. It was originally motivated by the observation that many of the differences researchers in neuroscience, endocrinology, and psychology have found to exist between individuals with high testosterone levels and those with low testosterone levels, are similar, if not identical, to the differences management researchers have observed between entrepreneurs and non-entrepreneurs. But we quickly came to realize this question is part of a much larger debate: Are business-related behaviors learned, or can they, at least in part, be explained by our biology? Most management research assumes the former and implicitly rejects the latter; in this view the human mind is basically a blank slate, a general-purpose computer programmed by our parents, our schools, and our culture (Pinker, 2002). This bias towards learned behaviors is pervasive. It so permeates sociology and psychology that it has been labeled the "Standard Social Science Model" (Markoczy & Goldberg, 1998; Tooby & Cosmides, 1992). The research presented in this paper explores the other possibility, that our evolved biology influences business-related behavior; specifically, whether individual differences in testosterone levels are related to the likelihood of significant involvement in a new venture. We find the expected association exists and that it is partially mediated by a psychological mechanism: risk propensity.

There is a history of studying the relationship between individual differences and entrepreneurship. However, this type of research had fallen into disfavor with many scholars (Gartner, 1988; Shaver & Scott, 1991) and, as Baron notes, many entrepreneurial researchers had concluded "that efforts to study entrepreneurs—their characteristics, their behavior, their

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skills, or their aptitudes—constituted a dead-end strategy which would ultimately add little to our understanding'' (2002, p. 227). Yet Baron finds it hard to accept that individual differences do not affect the manifestation of entrepreneurial behaviors This view resonates with a broad constituency: ''Entrepreneurs themselves, writers in the popular press, as well as those that have worked with entrepreneurs persistently ignore the recent findings that disconfirm the trait approach and continue to openly assume and act upon the idea that there exists entrepreneurial uniqueness among individuals (Mitchell et al., 2002, p. 95).

Indeed, the individual features prominently in contemporary definitions of the entrepreneurship domain. Shane and Venkatraman describe entrepreneurship as ''the nexus of two phenomena: the presence of lucrative opportunities and the presence of enterprising individuals'' (2000, p. 218). This definition has an environmental or contextual component (opportunities) and an individual component (the entrepreneur). Entrepreneurship occurs at the conjunction of the opportunity and the individual. It is the individual who identifies, pursues, and exploits a new business opportunity. Not all environments are equal in opportunities, and not all individuals are equally likely to recognize and pursue those opportunities. Even though there has been debate about whether individual factors affect entrepreneurial behavior (Gartner, 1988), most entrepreneurship scholars accept that the individual and individual differences do matter (Carland, Hoy, & Carland, 1988). The entrepreneur is a key component of entrepreneurship.

As part of this renewed interest in how and why individual differences influence entrepreneurship, Baron (2002) posed several compelling research questions, including: Why do some people (but not others) become entrepreneurs? Much of the research addressing this question has looked to individual differences in socialization, psychological attributes, and learning, as well as other cognitive processes. This paper takes a different approach and explores the linkage between entrepreneurial behavior and a physiological difference rooted in biology—testosterone level. To our knowledge, this is the first research linking a physiological difference to an entrepreneurial behavior.

This paper first reviews the testosterone and entrepreneurship literatures to identify similarities. However, by themselves, similarities are only suggestive, and do not provide a theory for why higher testosterone evokes entrepreneurial behaviors. We use the theory of evolutionary psychology to begin to forge this link (Buss, 1999; Cosmides & Tooby, 1997). Next, we propose a basic causal model, posit hypotheses consistent with this model, and then describe the method used to test these hypotheses. Finally, we discuss the findings and broader implications of the research.

Biology and behavior

When thinking about biology and behavior it is helpful to distinguish between proximate causes or factors, and ultimate factors. Increasingly, it is accepted that our physiology, including brain structure and processes, affects our daily behavior (Buss, 1997, 1999; Thornhill, Tooby, & Cosmides, 1997). These physiological factors, and the associated evolved psychological mechanisms, are proximate to the behavior. The evolutionary forces that produce a given genome and the accompanying physiology, are called the ultimate (or distal) factors.

Genes are the biological mechanism by which physiological characteristics are passed from generation to generation, but it is behaviors (not genes, or even physiological factors) that are subject to evolutionary selection (Dawkins, 1982). Genes are not directly connected to, nor do they determine our daily behaviors in a rigidly deterministic fashion. Genes result in a physiology that enables certain behaviors; those behaviors with a survival and reproductive advantage increase the frequency of their associated genes in subsequent generations, and those genes spread throughout the population. But genes do not determine behavior in any direct way; instead they express themselves in our physiology, including our endocrinology. These proximate biological characteristics influence behavior. It is through this indirect process, linking ultimate and proximate factors, that biological evolution results in some correspondence between genes and behavior.

Genes establish the potential for each individual's behavior but they do not dictate it (Lumsden & Wilson, 1981). Developing the height and endurance to play professional basketball requires not only the genetic potential but also adequate nutrition, physical conditioning, and learned skills. There is also a rich interaction between our endocrinology, other aspects of our physiology, and the social environment. Biology only creates a predisposition or potential for certain behaviors; it does not fully determine complex behaviors. Social behaviors are also affected by how and what an individual learns through formal education or less formal socialization processes. Nevertheless, biology still plays an important role, interacting in significant and interesting ways with these learning processes. Biosocial theory and research is just beginning to explore these rich interrelationships (Udry, 2000).

Testosterone research

Testosterone (T) is an androgen produced in the testes (in men), in lesser amounts in the ovaries (of women), and in the adrenal gland (in men and women). It peaks in late adolescence and young adulthood in males then slowly declines with age. It has a regular daily and seasonal variation (Dabbs, 1990a). An individual's

production rate of T is over 80% heritable (Meikle, Stringham, Bishop, & West, 1988). T levels affect both obvious physiological characteristics (e.g., muscle development) and more subtle attributes (e.g., brain development, structure, and processes) that may in turn affect cognitive and other psychological processes. T can affect our psychology by influencing brain structure during early development. It can also subtly affect ongoing neural processes by directly or indirectly activating receptors present in the adult brain. The effect of T upon specific neural mechanisms and how this influences behavior is only just being explored. However, at a more general level, T is one of the most studied of the endocrine hormones (Dabbs, 2000; Mazur & Booth, 1998a, 1998b).

Testosterone and occupation

Of particular interest to our research are the numerous studies relating T to occupation (although until now, no studies have compared the T levels of entrepreneurs and non-entrepreneurs). The largest study, in terms of sample size and breadth of occupation, was conducted with 4462 male military veterans (Dabbs, 1992). Dabbs' results indicated a strong relationship between general occupational class and individual differences in T level. Broadly, males in blue collar occupations have higher T levels than those in white collar professions, and farmers have the lowest T levels of all major occupational groupings. Finer-grained studies of T and careers have also been done with interesting results. For example, male trial lawyers have been found to have higher average T levels than male non-trial lawyers; the same holds true for female lawyers (Dabbs, Alford, & Fielden, 1998). Male construction workers have higher average T levels than lawyers (Dabbs & Morris, 1990) and, on average, female lawyers have higher T levels than female nurses (Schindler, 1979). As a group, male actors and professional athletes have higher T levels than ministers and farmers (Dabbs, de La Rue, & Williams, 1990). The preponderance of evidence supports a relationship between T and occupation. But these empirical relationships are not yet a theory.

Testosterone, risk-taking, evolution, and dominance

Testosterone production is a proximate biological factor influencing cognition and behavior. But understanding why it is encoded in our genes requires a distal or evolutionary explanation. From an evolutionary perspective, testosterone is primarily about dominance (Mazur & Booth, 1998b) and dominance in primates is about hierarchy and social structure (Kemper, 1990; Pierce & White, 1999). A dominance hierarchy occurs when members of a social group yield control over valued, non-plentiful resources to another member of that group. The hierarchy is the relative ordering or ranking of members by their resource prerogatives (Ellis, 1993; Fiske, 1991; Mazur, 1985). In our ancestral environment the member (or members) of a social group with privileged access to resources (food, water, mating privileges, assisted child rearing, etc.) had a reproductive advantage over their conspecifics. Their relative gene frequency would increase in the next generation.

The evolutionary social psychologists Leda Cosmides and John Tooby have concluded that, in the same way that evolution affects physical characteristics, it also moulds cognitive abilities into a bundle of specialized psychological mechanisms "... organized to collectively guide thought and behavior with respect to the evolutionarily recurrent adaptive problems posed by the social world" (1992, p. 163). Psychological mechanisms came about because they efficiently solved survival problems in our ancestral environment. [See Buss (1999, pp. 47–54) for an extended definition and discussion of psychological mechanisms.] The basis for these mechanisms is encoded in the genome and manifested in our physiology and endocrinology. Testosterone may be implicated in one or more of these psychological mechanisms. It is associated not only with certain physical characteristics such as strength and size, but also with psychological tendencies such as aggressiveness, risk-taking, and persistence. Individuals with these characteristics and tendencies were more dominant in the social world of our Pliocene fore bearers.

In our ancestral environment, climbing the social ladder entailed taking certain risks. An aspiring male would enter into a dominance contest by challenging the incumbent alpha male of his group. Threat, bluff, and overt aggression would ensue with all the attendant risks of injury or death for both parties (Wrangham & Peterson, 1996). Seeking the dominant position was a risk and required initiative, persistence, and assertiveness. But winning the dominance contest yielded the resource prerogatives of the α-position. As a result of cultural (and perhaps biological) evolution, aggressive dominance behaviors have become less accepted in most societies (Boehm, 2000; Boyd & Richerson, 2002; Richerson & Boyd, 1998; Sober & Wilson, 1998). But that does not mean that status-seeking and risk-taking behaviors have disappeared, or that testosterone no longer affects those behaviors (Burnham, 2002). Evolution rarely discards anything. Rather, in many instances, those T-induced behaviors are channeled into other avenues. Individuals direct their dominance-seeking (and risk-taking) propensities to other endeavors, like business, and elevate their status in socially acceptable ways (Frank, 1999).

Testosterone and entrepreneurship-related behaviors

Having established a general theoretical argument linking T with risk-taking and dominance-seeking

behaviors in our ancestral environment, we now examine the contemporary literature linking T with individual differences. The T literature is large, and this review identifies only those T-related behaviors of possible consequence in creating new business ventures. Subsequently, we will review the business literature to identify similar behaviors that have been associated with entrepreneurship.

Testosterone-related behavior

There is a large literature associating T with antisocial behaviors like violence and aggression. However, more benign, prosocial behaviors, such as risk-taking, assertiveness, fearlessness, and persistence have also been related to T. In a large study of military veterans, males with higher serum T levels were more likely to have taken part in risky activities, like combat; individuals with lower T levels were more likely to have been in a support or administrative positions (Gimbel & Booth, 1996). In a study of 195 male subjects, fearlessness and testosterone interacted to explain firefighting performance (Fannin & Dabbs, 2003). The association between T and fearlessness and persistence also extends to other species (Andrew & Rogers, 1972; Archer, 1977; Boissy & Bouissou, 1994; King, De Oliveria, & Patel, 2005).

Dominance-seeking and status-seeking behaviors have been associated with higher testosterone in animals (Mazur, 1976), and both women (Grant & France, 2001) and men (Schaal, Tremblay, Soussignan, & Susman, 1996). [See Mazur and Booth, 1998b for a comprehensive review.] A drive to dominate may be associated with the need for achievement and esteem from others (Maslow, 1940); needs that also correlate with entrepreneurship. Indeed, dominance is not just one behavior. Dabbs, Bernieri, Strong, Campo, and Milun (2001, p. 27) found that student subjects with higher basal levels of T engaged in social situations more quickly, were more focused, had a direct expressive style, and "displayed [a] more forward and independent manner". Within-sex results were similar for both men and women. These findings are consistent with other research that found high-T individuals to be more restless and action-oriented (Dabbs, Strong, & Milun, 1997).

Studies have also shown a positive relationship between T and independence, and between T and not needing the approval of others. High-T individuals, both men and women, are less likely to smile at, and show deference to, others (Cashdan, 1995; Dabbs, 1997). Independence was associated with high testosterone in a study of children, 15 boys and 22 girls (Strong & Dabbs, 2000). On average, high-T college students, both male and female, reported being more self-centered (as opposed to other-centered) than their low-T counterparts (Dabbs, Hopper, & Jurkovic, 1990; Harris, Rushton, Hampson, & Jackson, 1996).

Words used to describe high-T individuals include fearless, persistent, assertive, engaged, focused, expressive, independent, action-oriented, restless, self-centered, and non-deferential. T is common to all these behaviors and, as would be expected, this cluster makes a reasonably consistent set. Individuals with one of these attributes often exhibit others. But how are these behaviors related to entrepreneurship? In the next section we review the literature identifying individual differences associated with entrepreneurship (E).

Entrepreneurship-related behavior

Before reviewing the behaviors associated with entrepreneurship, some definition of the term is required. Entrepreneurship is not like testosterone. Testosterone has a physical presence; its absence or presence can be assessed by objective testing procedures. The same cannot be said of entrepreneurship. Its meaning is socially constructed and there is no single agreed definition of entrepreneurship, or of what behaviors define an entrepreneur. Different researchers have defined and identified entrepreneurs in different ways. For some, simply owning and managing a small business qualifies one as an entrepreneur (Masters & Meier, 1988). But most definitions include elements of risk-taking (McClelland, 1961; Mill, 1848; Stewart & Roth, 2001) and/or innovation (Carland, Hoy, Boulton, & Carland, 1984; Carland et al., 1988; Schumpeter, 1934). Growth aspirations and risk-taking are frequently linked to entrepreneurs on the premise that pursuing an innovation can be risky and successful innovations result in growth (Carland et al., 1984; Smith, Bracker, & Miner, 1987; Stewart, Watson, Carland, & Carland, 1999). Founding a new venture is a demonstrably risky undertaking (Aldrich & Martinez, 2001) and this activity has been used in many studies to define the entrepreneur (Bellu, Davidson, & Goldfarb, 1990; Brockhaus, 1980; Miner, 2000).

The diversity of definitions for entrepreneurship can be problematic. As Stewart and Roth conclude, definitions need to be internally consistent "and conceptually relevant to the research question(s)" (2004, p. 17). Different research questions require different definitions of what constitutes entrepreneurship. Accepting that entrepreneurship occurs at the conjunction of opportunities and individuals (Shane & Venkatraman, 2000), what behavior(s) makes one an "entrepreneur"? We are interested in understanding if biological differences can help explain why some individuals identify and pursue risky opportunities, while similarly capable individuals in the equivalent circumstances do not. The act of founding a new business venture requires the identification and initial pursuit of an opportunity (Gartner, 1994; Stewart, Carland, & Carland, 1996), and it is risky. This activity has a significant possibility of failure, and of losing one's investment of time, energy, resources, and

possibly reputation (Aldrich & Martinez, 2001). The straightforward, widely used, and easily reported act of significant involvement in the creation of a new venture was sufficient to define "entrepreneur" for the purposes of this study.

Common ground between testosterone and entrepreneurship

There is a high degree of correspondence between many of the behaviors associated with high-T individuals and those associated with entrepreneurs, even though the precise terminology used by E researchers differs from that employed by T researchers. The correspondence between T behaviors and E behaviors, while substantial, is not exact or complete. Differences are to be expected since the two research traditions have never been integrated. While there is considerable overlap between the entrepreneurship and the testosterone literatures, there are some E-related characteristics, like innovativeness that have no T equivalent. There is no theory or evidence linking T with innovativeness. Similarly there are T-related characteristics, like spatial ability (Moffat & Hampson, 1996) with no apparent parallel in the entrepreneurship literature.

The testosterone and entrepreneurship literatures complement each other nicely. Most of the empirical testosterone research has correlated individual differences in T with specific behaviors or decisions. Less often are differences in individual psychological attributes studied in relation to T. Mediated models, as suggested by evolutionary psychology, where the biological influences the cognitive/psychological which causes the decision/behavioral, are only occasionally studied. [See Fannin and Dabbs (2003) for an example.] The E literature has correlated an array of psychological variables with entrepreneurial behaviors. But this literature does not often attempt to explain the origin of individual differences in these psychological attributes. [See Sitkin and Weingart (1995) for an exception.] Evolutionary psychology suggests that biological effects upon behavior or decisions are mediated by the psychological. T has usually been studied as if it has a direct effect, unmediated by the psychological. Attempts to explain entrepreneurial behaviors have been correlated with individual psychological differences, but most often without exploring where those differences originate.

One key element featured in both entrepreneurship and testosterone research is risk. By definition, entrepreneurs engage in a risky behavior (new venture creation) and are generally believed to have a higher psychological propensity towards risk than non-entrepreneurs (Stewart & Roth, 2004). Similarly, high-T individuals take on risky situations more readily and more assertively than their low-T counterparts (Dabbs et al., 1997; Gimbel & Booth, 1996). Risk is a central concept in both literatures.

Entrepreneurs and risk-taking

Do entrepreneurs differ from non-entrepreneurs in their propensity and preference for, or perception of risk? More entrepreneurial research has been motivated by this question than perhaps any other. Recently, Stewart and Roth (2001, 2004) conducted a meta-analytic review of this subject and concluded that the preponderance of evidence suggests entrepreneurs have a greater propensity for risk than non-entrepreneurs. Even so, this popular view of entrepreneurs as risk-takers is still controversial (Brockhaus, 1980; Busenitz, 1999). Miner and Raju (2004) suggest entrepreneurs may simply perceive situations differently; using psychological processes, biases, and heuristics which lessen their perception of risk in certain situations. Like Busenitz, Baron believes entrepreneurs think differently than other people. He observes, "That entrepreneurs often underestimate risks and overestimate the likelihood of success are well-established facts. Why these tendencies occur, however, remains uncertain" (1998, p. 285). Simon, Houghton, and Aquino (1999, p. 125) evaluated the decision making characteristics of 191 MBA students and found that "individuals who perceive lower levels of risks were more likely to decide to form a venture." Of course, this systematic tendency among entrepreneurs suggests there is something specific to these individuals causing this type of cognitive bias.

Sitkin and Pablo define risk as "the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized" (1992, p. 10). Decisions (or behaviors) are said to be riskier to the extent that their outcomes are more uncertain or more difficult to attain, or associated with more extreme consequences. Decision outcomes are influenced by characteristics of the individual decision maker, the situational context, and the problem itself. This model suggests risk propensity and risk perception are mediators between risky behavior (or decisions) and a number of other effects. Specifically, they propose that *risk propensity*—the tendency of an individual to take or avoid risk—derives from risk preferences, outcome history, and inertia, while *risk perception*—an individual's assessment of risk—is a function of problem framing, domain problem familiarity, social influences, and organizational factors. Thus, propensity is an individual property with an innate component (risk preference) and a learned component (outcome history). Perception is driven largely by situational and contextual cues, although there is also an individual component (problem framing and familiarity). Though the match is not exact, this model of risky behavior is very similar to the Shane and Venkatraman (2000) conceptualization of entrepreneurship occurring at the nexus of individuals and opportunities (context). The Sitkin and Pablo model is also consistent with the heuristics and biases argument (Baron, 1998; Busenitz, 1999). The model contains an

explicit risk perception pathway, but still acknowledges the role of individual propensity in explaining risky behaviors. In subsequent empirical work, involving 101 male and female business students, Sitkin and Weingart (1995) found support for a mediated model of risky decision making behavior. Whatever their perceptions, it is generally accepted that entrepreneurs have a propensity for risk-taking—for engaging in the risky activity of new venture creation.

Conceptual model and hypotheses

Our basic conceptual model follows evolutionary psychology theory by positing a heritable physiological effect on overt behavior that is mediated by a psychological mechanism. The physiological variable employed is testosterone. The behavior of interest is significant involvement in the creation of a new venture. Risk-taking propensity was investigated as the psychological mediator because it is central to both entrepreneurship (Stewart & Roth, 2001, 2004) and testosterone research (Dabbs, 2000; Gimbel & Booth, 1996; King et al., 2005). Our model proposes that T level influences actions primarily by affecting psychological processes, or to use the terminology of evolutionary psychologists, by affecting psychological mechanisms (Cosmides & Tooby, 1997). Psychological mechanisms, in this case risk propensity, affect an individual's decisions and actions and the likelihood they will engage in a significant entrepreneurial experience. By placing risk propensity in a mediating role between an innate individual characteristic (T) and risky behavior (launching a new venture) this model is also consistent with Sitkin and Pablo (1992). As shown in Fig. 1, the model posits that T level effects are mediated by the psychological mechanism of risk propensity.

Consistent with the causal model depicted in Fig. 1, it is hypothesized that:

Hypothesis 1. T level is positively associated with risk propensity.

Hypothesis 2. Risk propensity is positively associated with the likelihood of entrepreneurial behavior.

If both hypotheses 1 and 2 are supported then risk propensity may be said to mediate between T and entrepreneurial behavior. Given the range of possible psychological mediating mechanisms that may occur in the presence of T, complete mediation is not expected. Our study focuses on risk propensity for the reasons discussed above.

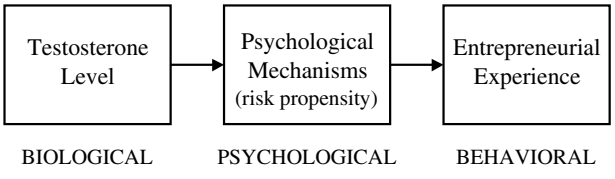

Fig. 1. Mediated model of testosterone effects upon enterpreneurial behavior.

Method

Testosterone levels are not static. They are subject to biological rhythms that influence T in a predictable fashion. T levels vary during the day and seasonally (Dabbs, 1990b). Therefore it is important to collect T samples under controlled conditions. Using an MBA student population allowed the saliva sampling to be carefully controlled and minimized inter-individual variability due to time of day, season of the year, or age. Participants in this study were all full-time MBA students attending a major North American business school. Table 1 provides the demographic profile of the full student body and of the subset of students who participated in this research.

Data collection

The MBA class was comprised of four sections of approximately 70 students each (both male and female). Timetables were arranged so the data could be collected from all four sections in a short time frame—two parallel sessions, in two consecutive classes, during the same day. Students were informed of the nature of the research and were free to opt out of any or all parts of the study, consistent with university research policies. To ensure confidentiality, student identities were not recorded. Numbers were assigned to all volunteers and these were used to link the data elements. Three data elements were collected from study participants: (1) entrepreneurial background and personal and demographic data, (2) Jackson Personality Inventory (JPI) scale, and (3) two saliva samples to be assayed for T.

Table 1
Characteristics of population and sample

	MBA student body (1st year cohort)	Study participants
Size (*n*)	272	110
Male (%)	75	100
Female (%)	25	0
Age	30	30
Prior work experience (years)	5.5	3.6
Ethnicity (%)		
Caucasian	61	46
Asian	32	37
Other	7	17
Undergraduate degree (%)		
Arts	34	45
Science/engineering	42	43
Other	25	12

Each data collection session commenced with a brief overview of the research and an explanation of the study protocols, followed by collection of the first of two saliva samples from each participant. Saliva was collected in polystyrene test tubes, individually labeled and pretreated with sodium azide as a preservative. Prior to the study, students were advised that if they wished to participate, they were not to consume any food or beverages (other than water), smoke, or chew gum for 1 h prior to the research session. After the first saliva sample was collected, participants completed a questionnaire that captured data on their demographics and entrepreneurial experience, and administered the psychological scale. After completing the questionnaire (≈20 min), students provided a second saliva sample. This concluded the data collection process. The saliva was maintained in sealed test tubes for 24 h at room temperature to allow mucins to separate and then was frozen to −20 °C. Samples were not thawed until the laboratory assays were performed. Data collection took place in February 2002; assays were done during May 2002.

The Jackson personality inventory

The Jackson personality inventory (JPI) is a well-developed general psychometric instrument to measure "interpersonal, cognitive, and value orientations likely to have important implications for a person's functioning." It is designed for use with normal populations and used in research settings "to contribute to the understanding of personality and its relation to behavior" (Jackson, 1994, p. 1). The JPI risk-taking scale is consistent with the Sitkin and Pablo (1992) definition of risk propensity: "Individuals who score highly on this scale are prone to exposing themselves to situations having uncertain outcomes. Low scorers tend to be more cautious in their approach to things." (Jackson, 1994, p. 23). Prior studies report satisfactory reliability and validity of the JPI (Stewart, 1996). In their recent meta-analysis, Stewart and Roth recommended the JPI risk scale "for assessing risk propensity because of the relative attractiveness of its measurement properties" (2001, p. 147). Most of the studies using the JPI compare entrepreneurs (and founders) with non-entrepreneurs and find entrepreneurs are higher in risk-taking (Begley, 1995; Begley & Boyd, 1987; Brockhaus & Horwitz, 1986; Carland & Carland, 1991; Carland, Carland, & Pearce, 1995; Stewart et al., 1999); although a few have found no significant group differences (Richard, 1989; Robbins, 1986).

The sample

All students were invited to participate but sample size constraints limited our study to males only. Of the population of 205 male students, 166 chose to fully participate in the study (81%). The number of female participants was small; 21 volunteers out of 67 female MBA students; and of those only four self-identified as having a prior entrepreneurial experience. (Subjects taking oral contraceptives were asked to exclude themselves from the study, because this form of contraception artificially suppresses T levels.) As a result, we judged the small number of females and in particular female entrepreneurs in our sample was unlikely to produce statistically meaningful results and assaying the female saliva would have incurred added expense.[1] Basal testosterone levels are substantially different for males and females and the effects of testosterone may differ, so pooling male and female data was inadvisable (Bateup, Booth, Shirtcliff, & Granger, 2002).[2]

Measures

Entrepreneurs

The entrepreneurial behavior of interest is full-time involvement in creating a new venture. This definition of entrepreneurship, though not universal, is frequently used as a simple, functional, operational measure (cf. Robinson, Stimpson, Huefner, & Hunt, 1991; Wooten, Timmerman, & Folger, 1999). This categorization was the dependent variable for our analysis. We studied business launches rather than outcomes and thus cannot predict a relationship between T and venture *success*.

Of the 166 male participants, 46 identified themselves as having been involved in a new venture start-up prior to their MBA studies. Student participants had no knowledge of their own T levels at the time of data collection. The researchers (professors in strategy and entrepreneurship) used a convergent sorting process to assess the extent to which the self-identified entrepreneurs were involved in a new venture. This procedure was blind, and done prior to determining T levels or analyzing the risk-taking scale scores. Each author independently assessed the description of the venture and the respondent's self-reported role in order to classify each respondent as an entrepreneur, possible entrepreneur, or non-entrepreneur. Our selection criteria were to accept as entrepreneurs those observations that both raters assessed as entrepreneurs (23 respondents) and those observations with one entrepreneur and one possible entrepreneur rating (6 respondents). We rejected observations classed as a non-entrepreneur by either rater (13 respondents). Both raters assessed the four remaining observations as possible entrepreneurs. These we re-examined and discussed, and finally classified as

[1] A different extraction procedure is required for analyzing female saliva.

[2] During the review process it was suggested that females be included in the analyses to examine sex differences, but the saliva samples were no longer available.

two entrepreneurs and two non-entrepreneurs. The inter-item correlation between the two raters is 0.81 with a raw proportion of agreement of 74%. Adjusted inter-rater agreement is 0.6 (for both the corrected S-coefficient (Bennett, Alpert, & Goldstein, 1954; Zwick, 1988) and for Cohen's (1960) kappa). This score falls within the "good" range for strength of inter-rater agreement (Landis & Koch, 1977).

A total of 31 subjects were retained in the entrepreneurship category. These individuals had led a new venture, personally investing in and managing the business. New ventures ranged from low-tech (coffee shops) to high-tech (web support for medical research laboratories). Other businesses included intelligence testing services, retail stores, manufacturers, and exporters. The majority of the ventures were based in Canada; five were in China and three in the United States. Nine of the 31 entrepreneurs reported that they had started more than one venture. Average annual revenues were C$600,000 and average firm size was seven employees. Eleven participants reported that their ventures were still in operation at the time of data collection. The 15 subjects eliminated from the entrepreneurial sample by the triage process did not have significant full-time involvement in the new venture; often they were part-time employees, passive investors, or board members. (Subjects who self-identified as entrepreneurs, but were disqualified after review by the researchers, were not included in the pool of non-entrepreneurial subjects.)

To serve as a comparison group, 79 male subjects with no entrepreneurial experience were included from the non-entrepreneurial pool. The final sample size was constrained by the assay procedures. The laboratory performed testosterone assays in fixed batch sizes based on "kits" of the reagent chemicals. Our final sample of 31 entrepreneurs and 79 non-entrepreneurs, each of whom provided two saliva samples, exhausted the available test kit capacity. The non-entrepreneurs were selected prior to the assays being performed and without knowledge of the participants' testosterone levels.

Testosterone

The saliva was thawed immediately prior to analysis and centrifuged, then submitted to a double ether extraction. The assay itself used a single Count-A-Count Total Testosterone Kit (Diagnostic Products, Los Angeles, CA), modified to accommodate the lower concentrations of T found in saliva. Details of the procedure are described in Moffat and Hampson (1996). All determinations were carried out in duplicate. The antibody is highly specific for T, with negligible cross-reactivity with other steroids (<5% for dihydrotestosterone). The sensitivity of the assay was 5 pg and the intra-assay coefficient of variation was 3%, averaged across low, medium, and high pools. All samples were analyzed by a technician who was blind to the hypotheses being tested and to the group membership of the study participants.

Reported T levels are the average of the two samples collected from each participant, expressed in picograms of testosterone per milliliter (pg/ml) of saliva. The testosterone values obtained were consistent with those reported in prior research (Moffat & Hampson, 1996; Read, 1993). Internal consistency reliability of the saliva samples was 0.85 (Nunnally, 1978). Some of the observed variation may be attributable to circadian variation; there was a 4% drop ($p < .10$) in testosterone from the first sample to the second sample (20 min separation). The alpha coefficient of the JPI risk propensity score was 0.81 for our sample, which is consistent with prior research reported by Jackson (1994). Data means, standard deviations, and correlation coefficients are presented in Table 2.

There is the potential for a causal ordering problem in the design of this study because the entrepreneurial behavior was exhibited some time prior to our measurement of T. However, the T levels in men show a high degree of stability under normal conditions, providing the influence of endogenous rhythms is taken into account. Vermeulen and Verdonck (1992) reported a strong correlation ($r = .85$) between a single point measure of T level and the mean of seven samples taken over one year. They concluded that "a single measurement may be considered to be a reasonably reliable parameter of the long term hormonal situation" (1992, p. 941). Other studies, using testosterone samples gathered over 6 years (Booth & Dabbs, 1993) and 10 years (Mazur & Michalek, 1998) have also reported that basal testosterone levels are predictable over time. By the end of adolescence, the basal level of testosterone is generally consistent from year to year, with a slow decline as each individual ages. "Men with relatively high T at one time tend to be relatively high at other times too... Furthermore, because basal levels are stable, it follows that they can be adequately measured at any time, *whether before or after the behavior*, and therefore can be adequately assessed in a cross-sectional study" (Mazur & Booth, 1998b, p. 361, italics ours). In the controlled conditions of the present study, the measured level of T should reflect long-term individual differences.

Table 2
Means, standard deviations, and correlations

	1	2	3	4	5
1. Entrepreneur	1.00				
2. Testosterone level	0.26*	1.00			
3. Age	0.04	−0.23*	1.00		
4. Time of day	−0.20*	−0.22*	0.04	1.00	
5. Risk propensity	0.27*	0.23*	−0.18	0.07	1.00
Mean	0.28	77.19	29.61	0.48	14.00
Standard deviation	0.45	21.83	3.55	0.50	4.08

* $p < .05$.

Control variables

We also included several control variables in our multivariate models: subject age, time of data collection, ethnicity, and undergraduate education. Age is included because of the inverse relationship between age and testosterone levels (Dabbs, 1990a; Lamberts, van den Beld, & van der Lely, 1997). As well, age may increase exposure to entrepreneurial opportunities. It was important to control for time period because T levels change during the day, declining significantly from early to late morning (Nieschlag, 1974). We were only able to collect data for this study during morning classes and the first and second data collection sessions were separated by a 50 min interval. The average T level was 12.5% lower in the later period. Ethnicity has been related to differences in testosterone levels (Ellis & Nyborg, 1992; Heald et al., 2003). In our study it was coded as Caucasian, Asian, or other. Finally, undergraduate program—engineering, arts or other—was included to account for possible differences in opportunity exposure and recognition.

Analysis and results

The initial step in our analysis compared mean scores between the entrepreneurs and non-entrepreneurs. We also conducted multivariate ordinary least squares (OLS) and logistic regression analyses. The data revealed no dfβ statistics in excess of 0.5, indicating the exclusion of any single observation moves the standardized regression coefficient by no more than one half of a standard error (Bollen & Jackman, 1990). The comparable diagnostic test for logistic regression, Pregibon's (1981) dβ score, also indicated no unduly influential observations. The Cook–Wiesberg diagnostic of the OLS regressions (reported in Table 4) indicated no heteroskedasticity problems (Cook & Weisberg, 1983). As well, joint tests of the T data for normality based on skewness and kurtosis did not indicate rejection of the null hypothesis of a normal distribution at the $p < .05$ level (D'Agostino, Balanger, & D'Agostino, 1990; Royston, 1991).

Mean difference analysis

Test results for mean differences are presented in Table 3. These results were consistent with the expectation that entrepreneurs have higher testosterone levels than non-entrepreneurs. The risk-taking scale scores were also significantly higher for the entrepreneurs relative to the non-entrepreneurs.

Multivariate analysis

Two equations representing our hypotheses are presented below. Significant coefficients on testosterone in the first equation and on risk propensity in the second equation are evidence that a mediation effect exists. A significant coefficient on testosterone in the second equation indicates mediation is partial rather than complete (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002; Shroat & Bolger, 2002). Results of the OLS and logistic regression models (including control variables) are reported in Table 4.

$$\text{Risk Propensity (RP)} = \alpha_0 + \alpha_1 \text{ Testosterone (T)} + \varepsilon_1 \quad (1)$$

$$\text{Entrepreneurship (E)} = \beta_0 + \beta_1 \text{ Risk Propensity (RP)} + \beta_2 \text{ Testosterone (T)} + \varepsilon_2 \quad (2)$$

The first two columns in Table 4 report standardized β-coefficients for OLS regression models on risk propensity. Column 1 contains only the control measures as independent variables. In column 2, testosterone is added to the equation (Eq. (1)) and the coefficient is positive and significant, as predicted by our hypotheses. Adding T significantly improved the explanatory power of the regression, as compared with the nested model of control variables [$F(1, 102) = 3.84$; $p < .05$].

Table 3
Means difference tests[a]

	Entrepreneur	Non-entrepreneur	Difference
Average T level (pg/ml)	86.1 (4.20)	73.7 (2.28)	12.4** (4.49)
Risk propensity	15.8 (0.47)	13.3 (0.49)	2.5** (0.84)
Sample size	31	79	

[a] One-tailed test, standard deviations in parentheses.
** $p < .01$.

Table 4
Mediated regression analysis

	OLS regression on risk propensity		Logistic regression on entrepreneurship	
		Eq. (1)		Eq. (2)
Age	−0.19†	−0.15	0.03	0.11
Time of day	0.02	0.06	−1.02*	−0.90†
Asian	−0.17	−0.14	−0.97	−0.71
Caucasian	−0.17	−0.14	−1.47*	−1.44*
Science degree	0.01	0.02	0.10	0.30
Arts degree	−0.27†	−0.25†	−0.04	0.65
Risk propensity				0.22**
Testosterone		0.19*		0.03*
Adj. R^2	0.086	0.110		
Pseudo R^2			0.084	0.194

* $p < .05$.
** $p < .01$.
† $p < .10$.

Columns 3 and 4 in Table 4 present logistic regression results, first with only control variables included and then with risk propensity and testosterone Eq. (2). Risk propensity and testosterone level are both positive, significant predictors of entrepreneurship. Sequential comparison of the nested models based on log-likelihood tests indicates that adding risk propensity and testosterone significantly improves the explanatory power when added to a less constrained model ($p < .05$). The analysis supports a relationship between T and new venture creation, partially mediated by risk propensity (MacKinnon et al., 2002).

Discussion

The results of our research support the primary hypothesis that individuals with higher salivary testosterone levels are more likely to behave entrepreneurially. More specifically, T is positively related to risk propensity (Hypothesis 1). There is also a positive relationship between risk propensity and the likelihood of an entrepreneurial experience (Hypothesis 2). Taken together these results indicate that risk propensity partially mediates the relationship between T and E.

Entrepreneurship involves the interaction of individuals and opportunities. In this research, we attempted to explain a portion of the variance on the individual side of the entrepreneurship equation. There are a wide array of social influences, learned behaviors, and other factors resulting in individual differences that affect entrepreneurial behavior. In our attempt to better understand the factors affecting an individual's choice to be an entrepreneur we focused upon a biological attribute, T level. Our findings indicate that risk-taking propensity is related to this heritable physiological attribute; suggesting this psychological attribute is in part innate. More specifically, individual differences in testosterone are associated with differences in risk-taking propensity, and thus with entrepreneurial behavior.

Increasingly, it is evident that the heuristics and biases used by entrepreneurs differ from those found in the non-entrepreneurial population. Our research indicates that a component of the entrepreneur's heuristics has a biological basis; what proportion remains to be determined. We do not believe any single biological difference will explain everything about entrepreneurial behavior. Nor do we believe that things innate to the individual necessarily explain most of the variance in entrepreneurial behavior. Nature and nurture almost always work together (Ridley, 2003). While the explanatory power of our model is significant, it is also consistent with the view that many other forces are at play when an individual acts to launch a new venture. Even so, the T-related findings are meaningful, especially so given the exploratory stage of this research. The effect sizes observed and the usable sample correspond to a statistical power value of 0.72 (Cohen, 1988). This research supports the view that biological differences matter to our understanding of entrepreneurial behavior. A specific heritable characteristic of each individual, their testosterone level, explains something about the likelihood of that individual being significantly involved in creating a new venture. Entrepreneurs may not be born; but what one is born with affects the likelihood of that person engaging in entrepreneurial activities.

Limitations and extensions

There are several limitations to the findings from this research. First, in the model, causation goes from T to E. But in this study T levels were measured after the entrepreneurial episode, not before. It is conceivable that having an entrepreneurial experience increases T, however such reverse causation is very unlikely. T levels can be affected by exogenous events (Mazur & Booth, 1998b), but these effects typically dissipate within a matter of hours, or days at the most. All our subjects were members of the same MBA year 1 class, and as such they were all part of the same social context. This similarity in social status reduces the likelihood of differential exogenous effects upon T.

Because an individual's basal T level is relatively stable; or, more accurately, declines at a slow, steady rate (for males) after early adulthood, a measurement of T after the event will be representative of T level at the time of the event. Barring major changes in lifestyle or health, any individuals' relative position within the same population would not be expected to change significantly with the passage of time. Approaches similar to the one employed by this study have been widely used by other T researchers (Dabbs et al., 1998; Fannin & Dabbs, 2003). Still the ideal study would be longitudinal; measuring T levels at an early point in the subjects' work lives, perhaps as they graduate from university, and then observing subsequent entrepreneurial behaviors.

Our study was done with male MBA students and is subject to the usual caveats about generalizing to the population of practicing entrepreneurs. However, only those subjects with actual new venture start-up experience were designated as entrepreneurs. Therefore, these results should generalize to entrepreneurs, at least to that subset of entrepreneurs that return to higher education after their entrepreneurial episode. There is no reason to suspect the T–E relationship would be different for this subpopulation. However, this possibility could be addressed directly by studying the T level of active entrepreneurs and comparing them to similar non-entrepreneurs. Such a study would require collecting testosterone samples under carefully controlled conditions.

Only males were included in the current study, for reasons already explained. Some prior research has found that T often has a similar (but not always identical) effect in a female population as it does in a population of males, even though the basal levels of T are much lower in females (Bateup et al., 2002; Dabbs et al., 1998; Harris et al., 1996). We suspect the same may be true for entrepreneurial behaviors but additional research is required to explore the T–E relationships within female populations.

In our study, the JPI measure of risk-taking propensity mediated the relationship between T and E. There is much prior theoretical and empirical work suggesting that differences in risk propensity distinguish entrepreneurs from non-entrepreneurs. However, other psychological mechanisms influenced by T may also mediate this relationship. Risk-taking is a good starting point but it is not the only possible psychological mediator. Future research should employ other psychological measures and explore how, if at all, they mediate the T–E relationship. The sensation-seeking scale developed by Zuckerman is especially interesting since it is grounded in a theory of psychophysiology and has been associated with differences in T, although not with differences in E. (Daitzman & Zuckerman, 1980; Daitzman, Zuckerman, Sammelwitz, & Ganjam, 1978; Zuckerman, 1994). It is conceivable, although we believe unlikely, that T has a direct effect upon E, unmediated by higher order cognitive or psychological processes (van Honk, Schutter, Hermans, & Putman, 2004). Again, more research is needed to address this question.

This study did not explore T's relationship to entrepreneurial success. Such a study would be extremely interesting and could be done, but would require a much larger sample and more resources. We suspect, as has been found in animal studies (Dufty, 1989), that the relationship would be an inverted U-shape. As indicated by our study, individuals with low T levels are less likely to exhibit entrepreneurial behavior. And those that do attempt to start a new venture are likely to be less persistent. At the other end of the spectrum, individuals with extremely high T may take unreasonable risks, persist with lost causes, be egocentric and over-controlling, and dominate their employees (Kets de Vries, 1985). This type of individual may initiate a new venture, but it is unlikely the venture would grow and prosper under their leadership.

The present study is a promising first step towards linking a heritable biological characteristic with a specific and interesting business behavior. Much more can and should be done. Until recently, testosterone (and other endocrines) could only be measured with blood samples, making this type of research difficult and costly. With the development of reliable techniques for salivary assays this research can be more easily and widely done. Such research promises to improve our understanding of how biological differences affect business behavior.

Implications and conclusion

This type of research is largely unexplored territory for scholars interested in management and business-related behavior. T research may help to explain much more about entrepreneurs than just the likelihood they will be involved in new venture start-up. There are a constellation of behaviors associated with testosterone. T may assist in explaining why some individuals have difficulty fitting into structured hierarchies, perhaps because they are not comfortable in a subordinate position (Burnham, 2002). Research of this type can go beyond just entrepreneurial behaviors. The possibilities are numerous.

The implications for practice raise interesting questions and possible dilemmas. First, it needs to be stated that this study was exploratory. Our research identified a specific, measurable, hormonal difference amongst individuals and related that difference to an observable business behavior. At this early stage it would be premature to offer any prescriptions for managerial practice. However, what if future research verifies and extends the general findings of this research, that individual biological differences influence business behaviors? What could practitioners do with this knowledge? More significantly, what *should* practitioners do with this knowledge?

Suppose future research demonstrates a relationship between T and new venture success. Should venture capitalists be allowed to test the T levels of would-be entrepreneurs requesting new venture funding? And then use that information as part of their decision to fund (or not fund) the entrepreneur's new venture proposal? Because individuals have no (natural) way to control their hormonal levels, many reasonable people would object to this type of testing. And, if such testing is not to be allowed, does that mean that we should not pursue the basic research to prove (or disprove) the relationship between a biological difference, like T level, and a business behavior, like venture success? We are intrigued by the prospects of further studies of this type and what might be found. But we recognize the findings from future research may raise ethical dilemmas.

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