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Biology and Selection Into Entrepreneurship—The Relevance of Prenatal Testosterone Exposure

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This study examines the relationship between prenatal testosterone exposure (PTE) and selection into entrepreneurship. We argue that the relationship between PTE and entrepreneurial intent is positive and mediated by general and domain-specific risk-taking related to financial investment and professional career. Using the second-to-fourth digit ratio (2D:4D) as noninvasive retrospective marker for PTE, we identify two-step mediation effects of PTE on entrepreneurial intent through both general and domain-specific risk-taking. To account for possible socialization-based effects, we control for gender and parental self-employment. Applying ordinary least squares (OLS) regression analyses and structural equation models, we provide empirical evidence for a biological association between 2D:4D and entrepreneurial intent.

Introduction

The relevance of individual differences for entrepreneurial behavior is widely acknowledged in the entrepreneurship literature. Entrepreneurship research based on the individual–opportunity nexus framework, for instance, stresses that individual differences play a critical role in individuals' decision-making processes (Eckhardt & Shane, 2010; Shane, 2003; Shane & Venkataraman, 2000; Venkataraman, 1997). Psychological differences may lead people to make different decisions about the exploitation of entrepreneurial opportunities even if they have the same information and skills (Shane). This study focuses on a very early phase of individuals' selection into entrepreneurship, namely the formation of entrepreneurial intent. While the formation of entrepreneurial intent is a different phenomenon than opportunity exploitation, both are linked (Dimov, 2007; Palich & Bagby, 1995; Thompson, 2009). Individual entrepreneurial intent is—as summarized by Thompson (p. 669)—"likely to remain an important construct in research relating to

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enterprising individuals, their cognitions of business opportunities, and their decisions of whether or not to risk exploiting them by creating new ventures." Individual differences, thus, may not only influence opportunity exploitation but also influence the formation of entrepreneurial intent (Souitaris, Zerbinati, & Al-Laham, 2007; Thompson). Our knowledge of the causes of different individual intentions to select into entrepreneurship, however, is still limited.

The formation of entrepreneurial intent causally precedes individuals' actions in starting new ventures (Bird, 1988; Krueger, Reilly, & Carsrud, 2000; Shook, Priem, & McGee, 2003). While entrepreneurial intent and its antecedents are well researched (e.g., Krueger et al.; Laspita, Breugst, Heblich, & Patzelt, 2012; Wilson, Kickul, & Marlino, 2007; Zellweger, Sieger, & Halter, 2011; Zhao, Seibert, & Hills, 2005; Zhao, Seibert, & Lumpkin, 2010), we do not know the extent to which biological factors may influence the formation of entrepreneurial intent. Biology may play a decisive role in the emergence of psychological differences, which in turn affect entrepreneurial decision-making processes and consequently the tendency to become an entrepreneur (e.g., Nicolaou, Shane, Cherkas, Hunkin, & Spector, 2008; White, Thornhill, & Hampson, 2007). Although socializing and learning processes continuously develop and shape predispositions through stimulating or hampering abilities, biological factors may still be highly relevant.

The exposure to testosterone in utero is one biological factor that can be argued to influence entrepreneurship. Prenatal testosterone exposure (PTE) affects early human brain development (Hines, 2010; Hönekopp & Watson, 2010; Lombardo et al., 2012) resulting in the formation of typical masculine patterns in physical appearance as well as behaviors (Auyeung et al., 2009; Brañas-Garza & Rustichini, 2011; Hines). Risk-taking is a common component of these masculine patterns (Byrnes, Miller, & Schafer, 1999). In this study, we present the theoretical foundations of the link between PTE and entrepreneurial intent, arguing that this relationship is mediated by individual risk-taking. Drawing on research linking general personality characteristics and entrepreneurship through more domain-specific characteristics (Baum, Locke, & Smith, 2001), we suggest to also distinguish between general and domain-specific risk-taking. Consequently, we emphasize the theoretical need for a two-step mediation model: PTE affects general risk-taking, which is linked to domain-specific risk-taking related to financial investments and professional career and only through the latter affects entrepreneurial intent.

We use the second-to-fourth digit ratio (2D:4D) as a noninvasive retrospective marker for PTE (Manning, 2002; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Medland et al., 2010). The digit ratio (2D:4D) is determined before birth and fairly stable over lifetime (Trivers, Manning, & Jacobson, 2006). It is therefore *exogenous* to subsequently observe personality characteristics, career choices, and selection into entrepreneurship. Using a sample of 448 students, we estimate the hypothesized two-step mediation model through general and domain-specific risk-taking related to financial investment and professional career. We also consider the possibility of the identified relationships of 2D:4D to reflect socialization (nurture) rather than biological effects (nature).

This research makes three contributions to the entrepreneurship literature. First, we complement prior research on the effects of PTE—measured by 2D:4D—on career choices (Sapienza, Zingales, & Maestripieri, 2009; Weiss, Firker, & Hennig, 2007), entrepreneurial performance (Guiso & Rustichini, 2011b; Trahms, Coombs, & Barrick, 2010; Unger, Rauch, Narayanan, Weis, & Frese, 2009), and exit from entrepreneurship (Guiso & Rustichini, 2011a). Since prior research does not focus on the relationship between PTE and selection into entrepreneurship, we close this gap by examining the link to the formation of entrepreneurial intent. Our results provide empirical evidence for a positive association between PTE and entrepreneurial intent. The observed size of this

relationship is similar to what we observe for parental self-employment, usually considered relevant for entrepreneurship (Parker, 2009), and similar to reported relationships between general personality characteristics and entrepreneurship (Rauch & Frese, 2007). Our research, however, does not suggest that biology determines who is (not) an entrepreneur, but only that PTE may have organizational effects on the fetal brain which in combination with subsequent socializing and learning processes influence individuals' future decision-making processes.

Second, we extend existing research by proposing and testing a two-step mediation model linking PTE to risk-taking and to entrepreneurial intent. We combine a mediation-by-risk-attitudes hypothesis proposed in previous research (Brañas-Garza & Rustichini, 2011; Sapienza et al., 2009; Trahms et al., 2010; Weiss et al., 2007) with research on domain-specific risk-taking (Dohmen et al., 2011; Figner & Weber, 2011) and general personality characteristics affecting entrepreneurship through domain-specific characteristics (Baum et al., 2001; Rauch & Frese, 2007). Specifically, we propose and find empirical support for a two-step mediation model where PTE affects general risk-taking which in turn influences entrepreneurial intent through domain-specific risk-taking. Thus, risk-taking is linked to PTE through its general component, but it is linked to entrepreneurial intent through its more domain-specific components. Over and above the mediated relationship, our results also point to a direct link between PTE and entrepreneurial intent that is not explained by our model.

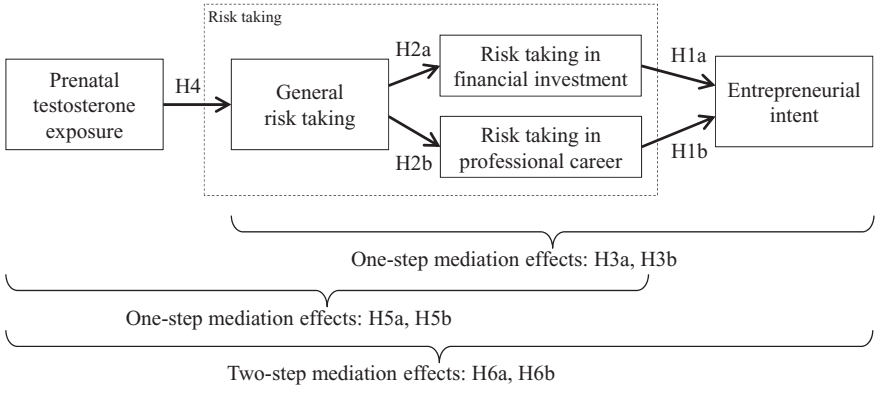
Third, we expand prior literature on the effect of PTE (measured by 2D:4D) on entrepreneurship by explicitly discussing ways through which this relationship can be spurious of socialization effects. The 2D:4D digit ratio displays a high inheritability and family resemblance (Medland & Loehlin, 2008; Paul, Kato, Cherkas, Andrew, & Spector, 2006; Voracek & Dressler, 2009) and a substantial correlation with gender (Hönekopp & Watson, 2010). As selection into entrepreneurship is affected by parental socialization and role modeling (cf. Laspita et al., 2012; Parker, 2009) and gender roles (Guiso & Rustichini, 2011a; Klapper & Parker, 2011; Verheul, Thurik, Grilo & van der Zwan, 2012), the relationship between 2D:4D and entrepreneurial intent could—even though considered exogenous—be spurious of socialization effects. We therefore control for gender and parental self-employment and demonstrate that these variables explain a significant part of the link between 2D:4D and entrepreneurial intent. There, however, also remains a noteworthy unique effect of PTE, independent of gender and parental self-employment, which points to the relevance of biological effects.

Theoretical Background and Hypotheses Development

This paper focuses on a very early stage of selection into entrepreneurship, i.e., the formation of entrepreneurial intent. Following Thompson (2009, p. 676), we define entrepreneurial intent as "a self-acknowledged conviction by a person that they will set up a new business venture and consciously plan to do so at some point in the future." Forming an entrepreneurial intent is usually an important preliminary stage in the emergence of entrepreneurship, which causally precedes any individuals' actions in establishing new ventures (Bird, 1988; Dimov, 2007; Krueger et al., 2000; Shook et al., 2003). The potential for (entrepreneurial) intent to convert into corresponding behavior is heavily dependent on factors outside the individual's personal control (Ajzen, 1991; Kolvereid & Isaksen, 2006), e.g., institutional contexts (Bowen & De Clercq, 2008). Focusing on later stages of selection into entrepreneurship, like comparing (nascent) entrepreneurs with nonentrepreneurs, would make it extremely difficult to separate the influence of PTE from

Figure 1

Conceptual Model



other external factors. Hence, we focus on people's own conscious intent to start a business anytime in the future regardless of all external factors that may eventually prevent the entrepreneurial action.

This section explicates the theoretical foundations of the link between PTE and entrepreneurial intent, specifically the link through risk preferences. We explain why it is important to distinguish between general risk-taking and more domain-specific risk-taking in order to understand the causal mechanisms that may link PTE to entrepreneurial intent. To do so, we first establish a link between entrepreneurial intent and risk-taking arguing that general risk-taking affects entrepreneurial intent through domain-specific risk-taking related to financial investments and to one's professional career. Next, we discuss causal mechanisms that link PTE to general risk-taking which in turn affects domain-specific risk-taking. From this, we conclude that the relationship between PTE and entrepreneurial intent is mediated in two steps by, first, general risk-taking and, then, domain-specific risk-taking related to financial investments and professional career. Our two-step mediation model and the corresponding hypotheses are graphically illustrated in Figure 1.

Risk-Taking and Entrepreneurial Intent

The assertion that entrepreneurs tend to be less risk averse than nonentrepreneurs is one of the oldest in entrepreneurship research (Douglas & Shepherd, 2002; Kihlstrom & Laffont, 1979; Knight, 1921). The underlying logic is that entrepreneurs often have to make decisions in uncertain environments and, in order to voluntarily select into such an occupation, are willing to bear risks and uncertainties avoided by others. Following this idea of a person–environment matching, researchers expect people who score high on risk propensity to be more attracted to entrepreneurship (Zhao et al., 2010). Similarly, risk-taking propensities are important antecedents to entrepreneurship within the individual–opportunity nexus perspective to entrepreneurship (Eckhardt & Shane, 2010).

On the one hand, there is substantial empirical support for the relevance of risk-taking for entrepreneurship based on large representative samples (e.g., Caliendo, Fossen, & Kritikos, 2009) and meta-studies (e.g., Rauch & Frese, 2007; Stewart & Roth, 2001; Zhao

et al., 2010). Of specific interest to our study is the meta-study by Zhao et al. (2010) that demonstrates the link between individuals' risk propensities and entrepreneurial intent. On the other hand, there are also empirical studies demonstrating a lack of evidence for the relevance of risk-taking propensities for entrepreneurship (e.g., Busenitz & Barney, 1997; Miner & Raju, 2004; Palich & Bagby, 1995).

It has been argued that individuals who select into entrepreneurship merely perceive less risk, which may result in a statistically insignificant effect of risk preference (e.g., Baron, 1998, 2004; Forlani & Mullins, 2000). While we would not deny the substantial and possibly larger influence of risk perceptions, almost all current decision theories suggest that both risk preferences (i.e., the willingness to accept these perceived risks) and risk perceptions matter (Figner & Weber, 2011).

Another explanation for the ambiguity of empirical results might be the negligence of domain-specific risk preferences and the focus on general risk preferences in empirical studies dealing with the relationship between risk-taking propensities and entrepreneurship. Baum et al. (2001) and Rauch and Frese (2007) argue that personality characteristics may influence entrepreneurial behavior only through domain-specific mediators. Consequently, domain-specific risk preferences should be taken into account since they may bridge the gap between general risk preference and entrepreneurship. Not only general risk preference but also other general personality characteristics considered to be relevant in entrepreneurship research show seemingly small effects because they influence entrepreneurial behavior only through more domain-specific mediators (Rauch & Frese). For instance, general personality characteristics and general competence convictions affect entrepreneurship through beliefs about domain-specific competences (Baum et al.). The latter is a reason for entrepreneurship research to focus more on entrepreneurial self-efficacy than general self-efficacy (Rauch & Frese). Similarly, locus of control affects actual behavior through domain-specific control beliefs (Rotter, 1975). General beliefs and preferences are the default when acting in unknown contexts. The more individuals get exposed to a specific context and gain related knowledge and experiences (e.g., through domain-specific socializations or individual domain-related experiences), the more domain-specific measures deviate from the general ones (Rotter). Thereby, domain-specific measures more strongly reflect domain-specific environmental influences. Consequently, they are more predictive for domain-specific behavior.

Theorizing on risk-taking behavior, Figner and Weber (2011) emphasize that risk-taking is not a single trait but a behavior influenced by characteristics of the situation, such as the decision context, the characteristics of the person, and the interactions between these two. The situational effect causes domain-specific measures of risk-taking to be just moderately correlated among each other (Dohmen et al., 2011; Hanoch, Johnson, & Wilke, 2006; Nicholson, Soane, Fenton-O'Creevy, & Willman, 2005). Furthermore, using general and domain-specific measures of risk-taking from a large representative socio-economic panel, Dohmen et al. (p. 541) report that instead of the general risk attitude measurement, the "domain-specific risk question is the best predictor of investment in stocks, participation in sports, self-employment, and being a smoker." Consistent with Rauch and Frese's (2012) general contention that the predictive power of personality can be enhanced if situational parameters are taken into account, we presume this to be the case for risk-taking too. That is, we expect that risk-taking propensities with a good match to the requirements of starting one's own business allow for higher validities in predicting selection into entrepreneurship than general risk-taking propensities.

Considering entrepreneurship as an element of one's career path (e.g., Douglas & Shepherd, 2002), risk-taking related to one's professional career is likely to matter more for selection into entrepreneurship than a general tendency to bear risks including, e.g.,

risk-taking with respect to gambling or health. Thus, when searching for domains of risk-taking that are more specifically related to entrepreneurship than general risk-taking, then risk-taking with respect to one's professional career is clearly a preferred candidate. Furthermore, entrepreneurship, especially when conceptualized as starting one's own new business, usually requires high investments in terms of time and financial resources and puts future income at risk (Baron, 2004). Risk-taking with respect to financial matters is, therefore, another domain of risk-taking clearly related to entrepreneurship. While in addition to these two domains of risk-taking also the domains of family relations or psychic well-being might be relevant (Liles, 1974), we believe that professional career and financial matters provide an appropriate starting point for studying more domain-specific conceptualizations of risk-taking within the context of entrepreneurship. In fact, in their analysis of a large representative socio-economic panel, Dohmen et al. (2011) find that in comparison to car driving, sports/leisure, and health, the two domains related to professional career and to financial matters exhibit the largest correlation with the status of being self-employed.

Summarizing our arguments and consistent with prior entrepreneurship research, such as Baum et al. (2001) and Rauch and Frese (2007), we suggest that the effective risk-taking propensity is a result of a possibly dispositional general risk-taking propensity adjusted by various domain-specific experiences. That is, if general risk-taking is related to entrepreneurship then it is related to it through more domain-specific measures. Based on theoretical arguments and prior empirical research, we expect measures of risk-taking related to professional career and financial investments to be good candidates for domain-specific measures related to selection into entrepreneurship. Hypotheses 1 to 3 summarize our arguments:

Hypothesis 1a: Risk-taking with respect to financial investment is positively related to entrepreneurial intent.
Hypothesis 1b: Risk-taking with respect to one's professional career is positively related to entrepreneurial intent.

Hypothesis 2a: General risk-taking is positively related to risk-taking with respect to financial investment.
Hypothesis 2b: General risk-taking is positively related to risk-taking with respect to one's professional career.

Hypothesis 3a: Risk-taking with respect to financial investment mediates the relationship between general risk-taking and entrepreneurial intent.
Hypothesis 3b: Risk-taking with respect to one's professional career mediates the relationship between general risk-taking and entrepreneurial intent.

PTE and Risk Preferences

Prenatal androgens—with testosterone being the one most frequently studied—have organizing effects on the developing nervous system and brain in the uterus (Goy & McEwen, 1980; Lombardo et al., 2012; Phoenix, Goy, Gerall, & Young, 1959; for summaries see Auyeung, Lombardo, & Baron-Cohen, 2013; Hines, 2010). Embryos are exposed to prenatal androgens, estrogens, and other hormones. The balance of these sex hormones affects the nervous system's development. The female fetus is exposed to testosterone at a much lower level than the male fetus; however, there is considerable variation in PTE within sexes (Auyeung et al.; Hines). Reviewing the literature on the role of hormones in the development of social and nonsocial cognition and the brain, Auyeung et al. conclude that prenatal hormone exposure is vital for early organization of the brain.

Fetal testosterone levels affect, for instance, brain morphology and also influence "later cortical gray matter volume, which has been observed to be sexually dimorphic" (Auyeung et al., p. 562). In contrast, "activational effects are short term and are dependent on current hormone levels" (Auyeung et al., p. 558). PTE, thus, primes the brain and thereby determines how it will react to current levels of testosterone. Hence, *PTE* and *current* testosterone levels are not alternative measures; they measure clearly distinct phenomena and their effects complement one another and even interact with each other during pregnancy, childhood, puberty, and the remaining life (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004; Breedlove & Hampson, 2002). Specifically, PTE is linked to fetal organizing effects on the endocrine system, which in adulthood moderate the activating effects of current hormone levels (Manning, Kilduff, Cook, Crewther, & Fink, 2014). Empirically supporting this view, van Honk, Montoya, Bos, van Vugt, and Terburg (2012) demonstrate that the negative effect of testosterone administration on cognitive empathy in the context of human bargaining behavior is boosted by high levels of PTE.

PTE affects brain organization, which in turn relates to basic characteristics such as people's altruism (Brañas-Garza, Kovárík, & Neyse, 2013) and their tendency to engage in cognitive reflection (Bosch-Domènch, Brañas-Garza, & Espín, 2014) but also to behavioral characteristics such as sexually differentiated childhood behavior in girls and in boys (Auyeung et al., 2009) and some sex-related cognitive, motor, and personality characteristics (Hines, 2010). These organizational effects are critically important for the masculinization and sexually differentiated behaviors across the lifespan (e.g., Archer, 2006).

Risk-taking is one of these sexually differentiated behaviors that are assumed to be affected by PTE (Byrnes et al., 1999). However, there are mixed empirical findings on the relationship between PTE—measured by 2D:4D—and risk-taking. Several studies do not find support for a statistically significant relationship (e.g., Apicella et al., 2008; Sapienza et al., 2009; Schipper, 2014; Trahms et al., 2010); others report significant correlations indicating that higher levels of PTE are associated with more risk-taking (e.g., Coates & Page, 2009; Dreber & Hoffman, 2007; Drichoutis & Nayga, 2012; Garbarino, Slonim, & Sydnor, 2011). Following the latter line of research, we expect that relatively higher levels of PTE are predictive of less risk-averse preferences.

Previous research theorizing on the relationship between PTE and risk preferences focuses on risk-taking in general and does not suggest relationships specific to different domains of risk-taking. In an empirical study, however, Stenstrom, Saad, Nepomuceno, and Mendenhall (2011) report a negative correlation between 2D:4D—and, thus, a significantly positive correlation between PTE—and financial, recreational, as well as social risk measures. No effect is reported for health and ethical risk domains. These authors, however, do not provide theoretical reasons why PTE might directly affect risk-taking in domain-specific ways. Furthermore, these authors do not test to what extent the observed effects might be driven by a more general risk-taking construct that is—due to interacting with domain-specific mechanisms—differently related to domain-specific risk-taking. Since prior research does not provide theoretical arguments or convincing empirical evidence of PTE directly affecting domain-specific risk-taking, we expect that the effect of person-specific PTE directly affects only general risk-taking which in turn influences domain-specific risk-taking. Thus, we hypothesize the following relationships:

Hypothesis 4: PTE is positively related to general risk-taking.

Hypothesis 5a: General risk-taking mediates the relationship between PTE and risk-taking with respect to financial investment.

Hypothesis 5b: General risk-taking mediates the relationship between PTE and risk-taking with respect to one's professional career.

Risk-Taking as Two-Step Mediator

Building on the links between PTE and risk-taking as well as between risk-taking and entrepreneurial intent, we expect that higher levels of PTE are positively associated with entrepreneurial intent. In particular, we propose that the link between PTE and entrepreneurial intent is mediated in two steps. We assume that PTE is related to general risk-taking and that domain-specific risk-taking is related to entrepreneurial intent. Consequently, the link between constructs of general risk-taking and of domain-specific risk-taking is not a mere appendix justifying the use of one construct or the other. Rather, the link between general and specific risk-taking is an essential and necessary part in linking PTE with entrepreneurial intent. The overarching relationship is summarized in the following two hypotheses:

Hypothesis 6a: The relationship between PTE and entrepreneurial intent is mediated in two steps by, first, the general risk-taking and, then, risk-taking with respect to financial risks.

Hypothesis 6b: The relationship between PTE and entrepreneurial intent is mediated in two steps by, first, the general risk-taking and, then, risk-taking with respect to one's professional career risks.

Methods

Sample

In winter term 2012/2013, we surveyed first- and second-year undergraduate students who attended an economics lecture at a large German university and who have not yet started a business. Despite being in a very early stage of their professional career, students have typically developed a general idea about their career goals (Scherer, Adams, Carley, & Wiebe, 1989), which includes entrepreneurial intentions (Obschonka, Silbereisen, Schmitt-Rodermund, & Stuetzer, 2011; Zhao et al., 2005). There is not only anecdotal evidence of very successful student entrepreneurship, such as Microsoft, Yahoo, Google, and Facebook, but entrepreneurship seems to be a viable option in our sample, too. Recognizing that, among the surveyed students, 2.9%[1] reported to have already started their own business suggests that these students' entrepreneurial intentions are meaningful, not just wishful thinking, and possibly translate into real behavior.

Besides the broad interest in studying students' entrepreneurial intent (e.g., Hmieleski & Corbett, 2006; Laspita et al., 2012; Wilson et al., 2007; Zellweger et al., 2011; Zhao et al., 2005), there are also methodological justifications for using student samples when examining entrepreneurial intent. First, the relationship between biology and entrepreneurial intent can be better identified when using samples of young people, because entrepreneurial intentions of younger people with less professional experience and less commitment to specific occupations are less likely to be influenced by external factors not

1. In fact, the share of those who have started a business of 2.9% (14 out of 490) roughly matches the 3.1% reported in the UK statistics for entrepreneurship among Destinations of Leavers from Higher Education (DLHE) for 2011/2012 (Higher Education Statistics Agency, 2015).

related to biology (e.g., post-hoc justification of irreversible decisions and experience-based overwriting of individual predispositions). Second, student samples provide a good balance between threats of reverse causality and sample selection biases. As recently demonstrated, being an entrepreneur influences risk preferences (Brachert & Hyll, 2014), which we hypothesized to influence selection into entrepreneurship. Thus, in order to avoid reverse causality problems, we might exclude all participants who have already started a business. Excluding those, however, might trigger sample selection biases. Consequently, we believe that studying individuals with a low likelihood of having already acted upon their entrepreneurial intent, but where the intent is possibly (not necessarily) translating into selection into entrepreneurship, is an appropriate choice. Intervening effects of entrepreneurial experience and professional experience should be much less of a concern for student samples as compared with samples of the general population. Focusing on students' entrepreneurial intent, instead of entrepreneurial intent across the general population, thus, reduces threats from endogeneity.

At the beginning of the questionnaire, students were informed that their identities are not recorded to ensure confidentiality and that the data will be used solely for scientific purposes. Participants were not informed about the specific nature of the research. From the initial 579 responses received, we excluded 86 observations because of missing values in at least one of the model variables. We further excluded responses with implausible answers and a few who already have started their own business. The item "I already started a business (please only mark 1 *or* 7)" with anchors "1 = does not apply at all" and "7 = fully applies" served two purposes. First, we excluded three participants who marked intermediate levels as this indicates that a lack of attention to the survey directions raises skepticism about responses to other items. Second, we excluded 14 participants who had already started a business.[2] By doing so, we avoid potential endogeneity problems. Further, we excluded 28 observations with implausible or inconsistent measures of finger lengths. As the hand preference displays strong interactions with effects of 2D:4D (Manning & Peters, 2009), we excluded 16 participants who indicate a left-hand preference. Comparing the restricted (final) and unrestricted sample shows no significant differences for gender (with a two-sample test of proportions), age, 2D:4D, and general risk-taking (with two-sample *t*-tests). The majority of the students are enrolled in business and economics (61%) or related fields such as health economics (8%); 19% study to become teachers, and 12% are majoring in other subjects. The average age is 22 years. Table 1 summarizes the descriptive statistics.

Model Variables

Entrepreneurial Intent. To measure entrepreneurial intent, we employ the multi-item Individual Entrepreneurial Intent Scale (IEIS) developed by Thompson (2009). Example items are "I intend to set up a company in the future" and "I never search for business start-up opportunities." All items (including the distractor items from Thompson) were translated into German, and participants were asked to evaluate the extent to which these statements apply to them; they responded on a 7-point scale ranging from "1 = does not apply at all" to "7 = fully applies." Cronbach's alpha for the IEIS is .78, indicating a sufficiently high level of internal validity.

2. Including those with entrepreneurial experience does not change the conclusion. Coefficients related to the hypotheses get larger except the coefficient for the link between 2D:4D and general risk-taking, which decreases by a negligible 2.5%. The analyses are available upon request.

Table 1

Summary Statistics and Correlation Table

			Pearson correlation coefficients										
Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
Entrepreneurial intent													
1 IEIS	2.84	1.38	(.78)										
2 LIK	1.80	1.33	.65***	1									
Digit ratios													
3 2D:4Dr	.99	.05	−.17***	−.20***	1								
4 2D:4Dl	.98	.06	−.06	−.10*	.49***	1							
Sex													
5 Female	.53	.50	−.25***	−.23***	.20***	.11*	1						
Parental self-employment													
6 Mother only	.06	.23	.14**	.06	−.08^{+}	−.09^{+}	.02	1					
7 Father only	.14	.35	.08	.07	−.10*	.01	−.09^{+}	−.10*	1				
8 Mother and father	.06	.23	.11*	.09^{+}	−.06	−.03	.05	−.06	−.10*	1			
Risk-taking													
9 General	4.50	1.38	.21***	.17***	−.12*	−.02	−.07	.00	.07	.10*	1		
10 Financial investment	2.71	1.43	.24***	.29***	−.11*	−.04	−.33***	.02	.08	.03	.23***	1	
11 Professional career	3.73	1.37	.25***	.25***	−.05	.03	−.31***	−.02	−.03	.12*	.31***	.33***	1

Significance levels: $^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Notes: N = 432, except for 2D:4Dl where N = 429. For IEIS, Cronbach's alpha is reported in parentheses on the diagonal.

LIK, entrepreneurial intent operationalized as perceived likelihood of starting a business, similar to Krueger et al. (2000); IEIS, entrepreneurial intent adapted from Thompson (2009); 2D:4Dr, 2D:4D of right hand; 2D:4Dl, 2D:4D of left hand.

Moreover, we employ a second measure of entrepreneurial intent in order to check the robustness of our results. Following prior research measuring entrepreneurial intentions by a *single item* that focuses on the perceived likelihood of starting a business (e.g., Kolvereid & Isaksen, 2006; Krueger et al., 2000), we also asked participants to evaluate the following statement "I will start a business during the next five years." Compared with Thompson's (2009) items, this item additionally captures expectations about successfully translating intentions into entrepreneurial actions (e.g., pessimism about finding a business opportunity or about acting upon it) and expectations about external pressure (e.g., unwanted but expected necessity entrepreneurship). This single item is by no means a perfect measure of entrepreneurial intent because single-item measures may lack reliability and should therefore be interpreted with caution. However, we use this measure as a robustness check to demonstrate that our results also hold for often employed measures of entrepreneurial intent that focus on perceived likelihoods of starting a business. The correlation between responses to this alternative entrepreneurial intent item (we refer to it as LIK) and IEIS is .65 and, thus, shows a substantial overlap, but not high enough to unambiguously indicate that the two measures reflect the very same aspects of entrepreneurial intent.

PTE. The standard practice in research on the effects of PTE is to employ the 2D:4D as a viable and promising retrospective biological marker (Manning et al., 1998; Pearson & Schipper, 2012).[3] PTE and 2D:4D are inversely related. That is, a higher level of PTE is associated with a lower 2D:4D ratio; corresponding effects must, therefore, be interpreted accordingly. Following Manning and Fink (2008), we employ a self-reported ruler-based measurement of 2D:4D. On four sheets of the questionnaire, two rulers were displayed which were arranged as a triangle with the rulers starting with zero at the point where they met. Students marked the length of the ring finger and the length of the middle finger (first sheet) and then marked the length of the middle finger and length of the index finger (second sheet) of the right hand. The same measurement was done for the left hand (third and fourth sheet). Verbal instructions were given how to do the measurement (e.g., how to position the hand and that the tip of a finger is relevant for measurement but not finger nails). We obtained the 2D:4D by dividing the length of the index finger (2D) by the length of the ring finger (4D). In order to reduce potential measurement errors, we dropped responses with implausible or unreliable 2D:4D measurements. We excluded 25 observations where the two measurements of the same middle finger of a hand (once in conjunction with the index and then together with the ring finger) differ by more than 10% and another three observations where the 2D:4D did not fall into the usually observed range of .8 to 1.2 (cf. Hönekopp & Watson, 2010). Visual inspection of the latter three observations showed that these outliers tend to be the result of errors when marking the length of fingers on rulers.

3. The empirical evidence for the relationship between 2D:4D ratio and prenatal testosterone exposure in humans is mainly indirect and based on correlational or quasi-experimental studies. In nonhuman studies, hormones have been applied in randomly assigned experiments. For example, the study by Zheng and Cohn (2011) provides experimental evidence that the 2D:4D ratio is a lifelong signature of prenatal testosterone exposure. Their study shows that "sexually dimorphic 2D:4D ratios in mice are similar to those of humans and are controlled by the relative levels of androgen and estrogen signaling in utero" (Zheng & Cohn, p. 16289). Similarly, Romano, Rubolini, Martinelli, Bonisoli Alquati, and Sainom (2005) have shown that a prenatal testosterone treatment masculinizes the digit ratio in birds. Overall, these findings tend to support the hypothesis that variation in testosterone levels during embryonic life significantly and causally affects digit ratios.

Risk-Taking Preferences. To record individual risk preferences, we adapted an experimentally validated measurement instrument from the German Socio-Economic Panel (Dohmen et al., 2011). We asked respondents to indicate their willingness to take risk in general and related to domain-specific dimensions. Participants responded on a 7-point scale from "1 = unwilling to take risks" to "7 = very prone to take risks." Following our theoretical framework, we focus on general risk-taking and domain-specific risk-taking with respect to one's professional career and financial investments.[4]

Control Variables

A correlation between 2D:4D and entrepreneurial intent may not reflect a causal biological effect of PTE on entrepreneurial intent but may represent a spurious correlation due to socialization effects. We elaborate on two possibly confounding social mechanisms. First, 2D:4D is sexually dimorphic with lower average 2D:4D in males compared with females (Hönekopp & Watson, 2010). Furthermore, previous research provides empirical evidence for gender differences in risk-taking and entrepreneurial behavior. Males are, on average, more willing to take risks than females (Croson & Gneezy, 2009) and a higher proportion of males engage in entrepreneurial activities as compared with females (Bönte & Piegeler, 2013; Klapper & Parker, 2011). Gender differences in risk-taking and entrepreneurship can result from gender roles (socialization) that can significantly influence males' and females' willingness to take risks (Croson & Gneezy) and their selection into entrepreneurship (Minniti & Nardone, 2007; Guiso & Rustichini, 2011a; Verheul et al., 2012). Therefore, socially induced gender effects could render a correlation between PTE, measured through 2D:4D, and risk-taking as well as entrepreneurial intent to reflect social rather than causal biological effects (cf. Guiso & Rustichini). It is therefore important to control for gender-related effects. We constructed a contrast code *female* (+1) versus *male* (−1).[5]

Second, for 2D:4D, there are substantial (additive) genetic effects of 57% to 81% (Paul et al., 2006; Voracek & Dressler, 2007, 2009), such that people born in families share similar digit ratios. Furthermore, within families, there is an intergenerational transmission at the level of biological antecedents of 2D:4D, e.g., through genes, as well as a socio-economic intergenerational transmission of entrepreneurial activities. Parents may act as role models for their children, but may also pass their family businesses to their children and may additionally provide resources such as financial capital, general human capital, or business- and industry-specific knowledge (Dunn & Holtz-Eakin, 2000; Lindquist, Sol, & van Praag, 2012; Sørensen, 2007). Since 2D:4D and family membership are correlated (through co-determination via genetic transmission within families) and the latter influences selection into entrepreneurship through social mechanisms, a correlation between 2D:4D and selection into entrepreneurship could be spurious of a socialization effect instead of reflecting a causal biological effect.[6] It is therefore important to control

4. Including other domain-specific risk dimensions (car driving, leisure and sports, health, and trust in strangers) into our analysis does not change our conclusions. In fact, none of these displays a statistically significant effect on entrepreneurship. Results are available upon request.

5. We use a contrast code because when entering a contrast code into an interaction term (as we will do in a robustness check), the main effect of the interacted variable can be interpreted as average effect, averaged over both sexes (Cohen, Cohen, West, & Aiken, 2003). This simplifies interpretation.

6. This effect becomes even stronger as both inheritance of 2D:4D and transition of entrepreneurship through role modeling and social identification are found to be particularly strong for same sex relationship: Inheritance of 2D:4D is found to be particularly strong through father–son lines raising (Voracek & Dressler, 2009).

for parental self-employment. Respondents indicated the professions of their mother and father and, thereby, could among others report that they are self-employed. We constructed three dummy variables for the cases when only the father is self-employed, only the mother is self-employed, and both mother and father are self-employed. Through these three variables, we can control for effects that are specific to mother, father, or both being self-employed.

Results

Table 1 reports descriptive statistics and bivariate correlations. Our 2D:4D measurement appears reliable as we can replicate previous findings. For example, females display larger 2D:4D and this effect is stronger for the right than for the left hand (Hönekopp & Watson, 2010; Manning & Fink, 2008). In our sample, females display larger 2D:4D for the right hand (r = .20) and to a smaller extent for the left hand (r = .11). Cohen's d's (a frequently employed measure of effect size) of .411 and .221 for the right and left hand, respectively, are similar (though slightly more polarized) to values that a meta-analysis reports for direct measurements, i.e., .353 and .284, respectively (Hönekopp & Watson).

The right-hand 2D:4D measure is robustly found to be more strongly affected by prenatal testosterone than the left-hand ratio (Hönekopp & Watson, 2010; Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004; Zheng & Cohn, 2011). The right-hand 2D:4D is also typically used in comparable studies analyzing the relationship between PTE and entrepreneurship (e.g., Guiso & Rustichini, 2011a, 2011b; Trahms et al., 2010) and, indeed, also our data indicate that the right hand 2D:4D is more strongly related to both operationalizations of entrepreneurial intent ($r_{IEIS} = -.17$ and $r_{LIK} = -.20$) than the left hand 2D:4D ($r_{IEIS} = -.06$ and $r_{LIK} = -.10$). Thus, we use the right hand 2D:4D for our analyses.

Overall Association Between PTE and Entrepreneurial Intent

Overall, the association between 2D:4D and entrepreneurial intent is negative and statistically significant ($r_{IEIS} = -.17$, $p < .001$), which also holds for the alternative measurement ($r_{LIK} = -.20$, $p < .001$). For the ease of interpretation, the reader is reminded that a higher level of PTE is associated with a lower digit ratio 2D:4D. Hence, a negative association between 2D:4D and entrepreneurial intent implies a positive association between PTE and entrepreneurial intent. Note that our estimates of the effect size are comparable to the effect sizes of other variables that are usually considered as relevant for entrepreneurship. For instance, parental self-employment is usually considered an important antecedent to entrepreneurship (Laspita et al., 2012; Parker, 2009) and the correlation between entrepreneurial intent and parental self-employment has been reported to be .15 (Laspita et al.). Furthermore, based on a meta-analysis, Rauch and Frese (2007) report uncorrected effect sizes for general personality characteristics on selection into entrepreneurship of .16. Given that prenatal testosterone levels might be even more distant

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Role modeling and social identification is found to be especially strong for same sex relationships between parents and children (i.e., father–son and mother–daughter) (Lindquist et al., 2012; Ruef, Aldrich, & Carter, 2003; Sørensen, 2007).

from intention formation and related selection processes than personality traits, a correlation of −.17 to −.20 between 2D:4D and entrepreneurial intent seems to be a noteworthy finding.

As argued above, the observed effect of 2D:4D on entrepreneurial intent can overlap with the related effects of sex and parental self-employment. Controlling for the effects of these variables by calculating partial correlations, we observe smaller but still statistically significant associations between 2D:4D and entrepreneurial intent for both operationalization ($r_{IEIS} = -.10$, $p < .05$; $r_{LIK} = -.15$, $p < .001$). Thus the association between 2D:4D and entrepreneurial intent (IEIS) overlaps with effects of sex and parental self-employment to about 40% (25% for LIK). Bias-corrected and accelerated bootstrapped confidence intervals (95%, 4,000 repetitions) for the difference between both total and partial correlation do not include zero ($\Delta r_{IEIS} = -.07$ with $CI_{95\%,IEIS} = [-.11, -.04]$, $\Delta r_{LIK} = -.06$ with $CI_{95\%,LIK} = [-.09, -.03]$) and, thus, indicate that the overlap between the effect of 2D:4D on entrepreneurial intent and related effects of sex and parental self-employment is statistically significant. In our remaining analyses, we therefore control for these effects.

Tests of Hypotheses

To test the effects of career- and investment-related risk-taking on entrepreneurial intent, i.e., hypotheses 1a and 1b, we regress entrepreneurial intent on both types of domain-specific risk-taking while controlling for 2D:4D and general risk-taking (Table 2, column 1). In support of hypotheses 1a and 1b, both measures of domain-specific risk-taking, related to financial investment and to professional career, respectively, display statistically significant effects. This also holds for the alternative measure of entrepreneurial intent, LIK (see Table 2, column 2). Thus, we can support hypotheses 1a and 1b.

Next, we regress domain-specific risk-taking on general risk-taking while controlling for 2D:4D (Table 2, columns 3 and 4). In support of hypotheses 2a and 2b, we find that general risk-taking is statistically significantly associated with both types of domain-specific risk-taking, i.e., risk-taking related to financial investments (column 3) and to one's professional career (column 4).

Hypotheses 3a and 3b suggest that general risk-taking indirectly affects entrepreneurial intent through the two types of domain-specific risk-taking related to financial investments and one's professional career. To test these indirect effects, we follow well-established methods suggested by Preacher and Hayes (2008). The indirect (mediated) effects are calculated as the product of the effects along the paths constituting the indirect effect. For the significance test, we estimate bias-corrected accelerated bootstrapped confidence intervals; an indirect effect is considered statistically significant at the level of p if the $(1\text{-}p)$-confidence interval does not include zero (Preacher & Hayes). The first two rows in Table 3 report the indirect effects of general risk-taking on entrepreneurial intent through risk-taking related to finanical investment and one's professional career, respectively. Both effects are statistically significant. This also holds for the alternative measure of entrepreneurial intent, LIK (mediation tests available upon request). Thus, our results support hypotheses 3a and 3b.

To test hypothesized effects related to PTE, we first regress general risk-taking on 2D:4D (Table 2, column 5). We observe that the estimated effect of 2D:4D is negative and statistically significant. As we control for between-gender variation of 2D:4D by including sex, we already rule out that our results are driven by between-sex variations of 2D:4D. As additional robustness check, we also allow the within-sex variation to have different effects on risk-taking for males and females, respectively. Including an interaction

Table 2

Summary of Regression Analyses

Column			1	2		3		4		5	6
			Entrepreneurial intent			Risk-taking					
Dependent variable			IEIS	LIK		Investment		Career		General	General
2D:4D			–0.082 (0.046)$^{+}$	–0.132 (0.046)**		–0.016 (0.046)		0.044 (0.045)	H4:	–0.099 (0.049)*	–0.108 (0.051)*
Risk-taking	General		0.109 (0.048)*	0.044 (0.048)	H2a:	0.202 (0.045)***	H2b:	0.290 (0.044)***			
	Financial investment	H1a:	0.103 (0.050)*	0.169 (0.049)***							
	Professional career	H1b:	0.121 (0.051)*	0.181 (0.051)***							
Sex	Female (+1) versus male (–1)		–0.156 (0.050)**	–0.084 (0.049)$^{+}$		–0.309 (0.046)***		–0.305 (0.044)***		–0.049 (0.049)	–0.048 (0.049)
	Female versus male × 2D:4D										0.036 (0.050)
Parent self-employment	Father only		0.195 (0.132)	0.148 (0.130)		0.110 (0.131)		–0.188 (0.126)		0.201 (0.140)	0.189 (0.141)
	Mother only		0.617 (0.193)**	0.252 (0.191)		0.131 (0.192)		–0.072 (0.186)		0.040 (0.206)	0.038 (0.206)
	Mother and father		0.410 (0.199)*	0.268 (0.197)		0.143 (0.197)		0.436 (0.190)*		0.460 (0.210)*	0.467 (0.210)*
Constant			–0.085 (0.052)	–0.047 (0.051)		–0.013 (0.052)		0.006 (0.050)		–0.064 (0.055)	–0.070 (0.056)
R^2 (F statistic)			0.163 (10.33)***	0.167 (10.60)***		0.156 (13.07)***		0.200 (17.75)***		0.032 (2.788)*	0.033 (2.407)*

Significance levels: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: N = 432. All variables except dummy variables (gender and parent self-employment) standardized. Standard errors in parentheses.

LIK, entrepreneurial intent operationalized as perceived likelihood of starting a business, similar to Krueger et al. (2000); IEIS, entrepreneurial intent adapted from Thompson (2009); H(1a, 1b, 2a, 2b, 4), references to hypotheses related to corresponding coefficients.

Table 3

Summary of Mediation Analyses

One-step mediation effects:			
H3a:	General risk-taking → financial risk-taking → entrepreneurial intent (IEIS)	0.021*	[0.003, 0.050]
H3b:	General risk-taking → career risk-taking → entrepreneurial intent (IEIS)	0.035*	[0.004, 0.072]
H5a:	2D:4D → General risk-taking → financial risk-taking	–0.020*	[–0.050, –0.001]
H5b:	2D:4D → General risk-taking → career risk-taking	–0.029*	[–0.066, –0.001]
Two-step mediation effects:			
H6a:	2D:4D→General risk-taking → financial risk-taking → entrepreneurial intent (IEIS)	–0.002*	[–0.008, –0.000]
H6b:	2D:4D→General risk-taking → career risk-taking → entrepreneurial intent (IEIS)	–0.003*	[–0.012, –0.000]

Significance levels: * $p < 0.05$

Notes: Estimations and significance tests for indirect effects based on bias-corrected accelerated bootstrapped confidence intervals corresponding to desired confidence level (10%, 5%, 1%, 0.1%) with 4,000 repetitions (Preacher & Hayes, 2008). We report the 95% confidence intervals. Effect considered significant at level p if the (1-p)-confidence interval does not include zero; H(3a, 3b, 5a, 5b, 6a, 6b), references to hypotheses related to corresponding coefficients.

between sex and 2D:4D (see Table 2, column 6) does not reveal a statistically significant difference in the relationship between 2D:4D and general risk-taking between females and males.[7] Thus, we can keep the simpler model of gender-independent effects of 2D:4D on general risk-taking. In sum, we find support for hypothesis 4 suggesting that PTE (2D:4D) is positively (negatively) related to general risk-taking.

Hypotheses 5a and 5b suggest that PTE positively affects the two types of domain-specific risk-taking through general risk-taking. Table 3 (rows 3 and 4) reports estimates of these indirect effects and related confidence intervals. As these confidence intervals do not include zero, we can consider both effects being statistically significant, which provides support for hypotheses 5a and 5b. Furthermore, note that 2D:4D has neither a statistically significant effect on risk-taking related to financial investments nor on risk-taking related to one's professional career (Table 2, columns 3 and 4). This suggests that the effect of PTE on domain-specific risk-taking is mainly explained by an indirect effect through general risk-taking.

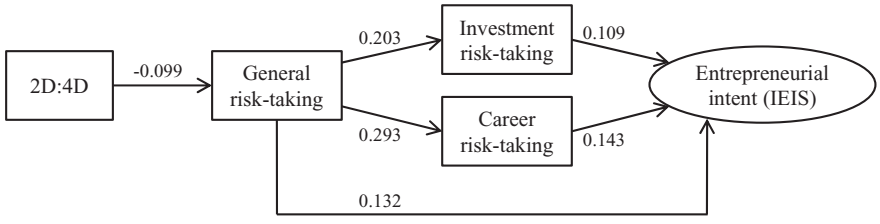
Hypotheses 6a and 6b further suggest that 2D:4D indirectly affects entrepreneurial intent in two steps through general risk-taking and the two types of domain-specific risk-taking. Table 3 (rows 5 and 6) reports estimates of these indirect effects and related confidence intervals. We observe that both two-step mediation effects are statistically significant, which lends support to our hypotheses 6a and 6b. This also holds for the alternative measure of entrepreneurial intent, LIK (mediation tests available upon request).

Besides testing the hypothesized mediation effects, evaluating the direct effects of 2D:4D sheds light on the question of whether or not we observe a full or a partial mediation. In Table 2, we observe that the coefficent of 2D:4D for its effect on entrepreneurial intent (IEIS) is statistically significant at the 10% level (column 1), and for the robustness check with LIK, it is statistically sigificant at the 1% level. Hence, while much of the effect of 2D:4D on entrepreneurial intent is mediated through risk-taking, especially for the multi-item measurement, there is the possibility of a partial mediation and, thus, an additional direct effect.

7. We do not argue that there are no differences, but in our sample, the related effect sizes might be too small to be reliably detected.

Figure 2

Structural Equation Model (Robustness Check)



Note: Structural equation model with entrepreneurial intent (IEIS) as latent construct. For all endogenous variables, we included sex and parental self-employment (only father, only mother, mother and father self-employed) as control variables: Being female negatively affects both types of domain-specific risk-taking (financial investment and professional career) and entrepreneurial intent ($p < .05$). Mother and father self-employed positively affects general risk-taking, risk-taking with respect to one's professional career, and entrepreneurial intent ($p < .05$). Only mother self-employed also positively affects entrepreneurial intent ($p < .05$). For the rest of the model, we report paths that are statistically significant with $p < .05$. We report standardized path coefficients.

Robustness Check: Structural Equation Model

Instead of ordinary least squares (OLS) regression analyses we can also employ structural equation models to estimate the system of equations reported in Table 2 (columns 1, 3, 4, and 5), which allows modeling entrepreneurial intent (IEIS) as a latent variable. For estimations of variables with entrepreneurial intent, we should observe slightly larger coefficients (due to controlling for the measurement error in entrepreneurial intent); all other coefficients should remain stable. Figure 2 summarizes the estimations. The results meet our expectations and are consistent with our earlier regression analyses.

Discussion

Summary

This study develops and empirically tests a model that links PTE to general risk-taking, domain-specific risk-taking, and entrepreneurial intent. Our empirical results indicate a positive and statistically significant association between PTE—measured by 2D:4D—and entrepreneurial intent. In line with our model, the empirical results point toward two-step mediation effects of PTE on entrepreneurial intent through general and domain-specific risk-taking related to financial investments and one's professional career. While a large part of the effect of PTE is mediated through the different types of risk-taking (indirect effects), we have indications that there remains a significant *direct* effect. This implies that there might be additional mechanisms through which PTE is linked to entrepreneurship. The estimated effect size of the total PTE effect—the sum of direct and indirect effects—is comparable to the effect sizes of other variables that are usually considered as important antecedents to entrepreneurship, e.g., parental self-employment (Laspita et al., 2012; Parker, 2009) and general personality characteristics (Rauch & Frese, 2007), which indicates its empirical relevance.

Previous research links PTE with entrepreneurship through the willingness to take risks, conceptualized in a uni-dimensional fashion (e.g., Garbarino et al., 2011; Trahms

et al., 2010). We advance this research by emphasizing the need for a two-step mediation model. Its unique feature is the specific link of risk-taking as mediating variable to its antecedents and its consequences. One the one hand, PTE is found to affect general risk-taking, implying that it is not specific to the context and domain of entrepreneurship. On the other hand, the link to entrepreneurial intent works through characteristics that are more domain-specific, i.e., risk-taking related to financial investments and to one's professional career. Thus, to establish the link between PTE and entrepreneurship, our study draws attention toward the need to consider both general and domain-specific risk preferences.

We carefully explore and quantify the degree to which the hypothesized biological relationship between PTE and entrepreneurial intent is possibly confounded by socialization-based effects related to sex and parental self-employment. Our analysis reveals that parts of the effect of PTE on entrepreneurial intent overlap with the effects of sex and parental self-employment. It is noteworthy, however, that even after controlling for these two variables, we still find two-step mediation effects of PTE on entrepreneurial intent through general and specific risk-taking.

All in all, our empirical results suggest that biology plays a relevant role for explaining individual differences in risk-taking and, consequently, in selection into entrepreneurship. Our findings indicate that not only nurture but also nature is relevant for individuals' selection into entrepreneurship. In line with the view that "human mind is [not] like a blank slate which is written upon by our parents, schools and culture" (White et al., 2007, p. 451), our results add to the empirical evidence that entrepreneurial behavior is related to biological factors such as genes and hormones (e.g., Guiso & Rustichini, 2011a; Nicolaou et al., 2008; Sapienza et al., 2009; Trahms et al., 2010; Weiss et al., 2007; White et al.).

Limitations and Future Research Directions

Before discussing the implications for future research, we acknowledge three limitations of our study, which offer opportunities to improve upon our analyses. First, the usefulness of studying entrepreneurial intentions of undergraduate students might be challenged because students' intentions may never translate into actual entrepreneurial activities, and consequently, it might be more meaningful to focus on actual entrepreneurs instead. We argue, however, that our dependent variable (entrepreneurial intent) and the student sample are appropriate to empirically examine the role of PTE for selection into entrepreneurship whereas focusing on actual entrepreneurial behavior or using samples drawn from people at later stages of their professional life are likely to result in biased estimates. Studying entrepreneurial intentions of students avoids substantial endogeneity problems and, thereby, contributes to a better understanding of the relationship between biology and selection into entrepreneurship.

In the theory section, we explain that entrepreneurial intentions are closer to individuals' possibly biologically affected dispositions than the overt status of being an entrepreneur. Furthermore, comparing entrepreneurs with nonentrepreneurs with respect to antecedents of their selection into entrepreneurship suffers from endogeneity problems through reverse causality. While we can safely assume that selection into entrepreneurship does not affect the PTE, recent empirical evidence suggests that such a reverse causality cannot be excluded for risk-taking, which we hypothesized as a mediating variable. Based on data from a large panel study, Brachert and Hyll (2014) demonstrate that self-employment may lead to endogenous changes in the individual willingness to take risks

with respect to one's career. It is therefore appropriate to focus on entrepreneurial intent of people without experiences with their own start-up.

While the method section motivates the use of a student samples instead of a sample drawn from the general population, it is not obvious to what extent our conclusions can be generalized to such a broader population. As discussed above, the more experiences people gain in life and during their professional careers, the more external factors might weaken the influence of biological factors. Testing the hypothesized effects would then require more complex models anticipating such intervening experience-based effects. As such, we believe that for initial tests of fundamental effects, like the role of PTE, undergraduate students, who are usually about to start their professional career, constitute an appropriate sample (cf. Bello, Leung, Radebaugh, Tung, & van Witteloostuijn, 2009). Future research could further explore to what extent these effects are mitigated or even leveraged by people's professional and entrepreneurial experiences.

Second, an important limitation results from two types of measurement error in our key variable. The first type of measurement error is introduced by using 2D:4D to proxy PTE. Even though the validity of 2D:4D as marker for PTE is supported by a number of studies (e.g., Hönekopp & Watson, 2010; Lutchmaya et al., 2004; Manning, 2002; Manning et al., 1998; McIntyre, Cohn, & Ellison, 2006), multiple factors affect 2D:4D, such that 2D:4D does not perfectly reflect PTE (cf. Dressler & Voracek, 2011; Medland et al., 2010). While possibly influencing the finger length, we did not collect data on past injuries of relevant fingers. Thus, we cannot improve the reliability of the measurement by exlcuding those participants who broke relevant fingers (cf. Stenstrom et al., 2011). The second type of measurement error is introduced by the self-measurement of 2D:4D. Studying the reliability of self-measured 2D:4D based on the BBC (2005) Internet study with more than 450,000 participants, Hönekopp and Watson estimate the reliability of the self-measured 2D:4D to be 46% lower than for expert-measured digit ratios. However, as both types of measurement error tend to result in a downward (attenuation) bias of estimated effect sizes, our estimates of the relationship between 2D:4D and entrepreneurial intent may only represent the lower bound of the true effect size. In order to provide a rough estimate of the "true" effect size, we could simply correct for the measurement error in 2D:4D by incorporating the unreliability resulting from self-reported digit ratio as compared with expert measurements ($1 - .46 = .54$). This would result in a corrected correlation of $-.26$[8] (compared with our baseline result of $-.17$). Such correction procedures, however, run the risk of providing even more biased results (Schmidt & Hunter, 1996), such that these higher estimates should not be overemphasized. Nevertheless, future research could employ more reliable measures of PTE, e.g., by using more appropriate measurement tools and software, which is likely to result in higher estimated effects sizes.

Third, our study focuses on PTE leaving aside the analysis of *current* testosterone levels (e.g., in blood or saliva), which is often used in studies on hormones and selection into entrepreneurship (e.g., van der Loos et al., 2013; White, Thornhill, & Hampson, 2006). PTE is clearly distinct from *current* testosterone levels (Baron-Cohen et al., 2004; Breedlove & Hampson, 2002). Current testosterone levels are far from being a predisposition or a stable biological marker because the level can fluctuate substantially over

8. This correlation is based on also correcting for the measurement error in entrepreneurial intent (IEIS) approximated by Cronbach's alpha (0.78). Applying structural equation modeling, we can also estimate the correlation between two latent variables, entrepreneurial intent (IEIS) and 2D:4D that is measured by our observed 2D:4D with a measurement that is about 46% less reliable. The resulting estimate for the correlation is $-.25$, which is consistent with the simpler correction procedure.

the day and course of lifetime due to varying personal and situational circumstances (Hönekopp & Watson, 2010). Moreover, recent studies indicate that PTE and current levels of testosterone have distinct effects (Folland, McCauley, Phypers, Hanson, & Mastana, 2012; Hönekopp, Bartholdt, Beier, & Liebert, 2007; Hönekopp & Watson). While PTE affects brain organization, in later life, hormones such as testosterone during puberty are thought to "activate or fine-tune the early organization of the brain, although the exact relationships between these two time periods are far from clear" (Auyeung et al., 2013, p. 567). Hence, studies linking current testosterone levels to selection into entrepreneurship cannot be generalized to explain the effect of PTE. Future research should address both and perhaps evaluate their interactive effects, which have been demonstrated in other challenging contexts such as sports and social dilemma situations (e.g., Manning et al., 2014; van Honk et al., 2012), in the context of the selection into entrepreneurship.

Our findings suggest further directions for future research; we elaborate on four points. First, since our arguments suggest that PTE influences risk-taking and selection into entrepreneurship through its effects on brain organization, our study supports scholars suggesting that entrepreneurship research can benefit from incorporating methods and technologies from neuroscience (de Holan, 2014; Lombardo et al., 2012; Nicolaou & Shane, 2014), which includes, e.g., brain scans via functional magnetic resonance imaging (Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015). These methods can provide a more comprehensive picture of the link between hormones and behavior. Through establishing the link between entrepreneurship and PTE, with the latter having known effects on specific parts of the brain (for an overview, see Auyeung et al., 2013), our results could tentatively suggest what neurological differences may be causally related to selection into entrepreneurship.

Second, finding indications of a direct relationship between PTE and entrepreneurial intent over and above a mediated effect through risk-taking suggests that future research should explore additional mechanisms through which 2D:4D can be linked to entrepreneurship.[9] For instance, Brañas-Garza and Rustichini (2011) show that 2D:4D is not only negatively related to risk-taking but also to abstract reasoning capabilities. This negative capability effect might explain why Guiso and Rustichini (2011b) find in a large sample of entrepreneurs that 2D:4D is also negatively associated with entrepreneurial skills and firm growth. Consistent with such capability and skill effects, Trahms et al. (2010) identify a negative direct effect of 2D:4D, but also a positive indirect effect of 2D:4D through strategic goal commitment on entrepreneurs' revenues. Thinking style, skills, and goal commitment are dimensions along which entrepreneurs are assumed to differ from other people (Baron, 2004). While these dimensions have been explored for entrepreneurial performance, corresponding analyses for selection into entrepreneurship are still missing.

Third, while developing the two-step mediation framework, we recognized that there is a lack of specific and rich-of-detail theorizing on the link between general and domain-specific preferences and beliefs like risk-taking. While seminal contributions, such as Baum et al. (2001) and Rauch and Frese (2007), have demonstrated the relevance of this link for theorizing about antecedents of entrepreneurship, we do not see much of theory-driven research examining this link in more detail. Our study clearly suggests that research on the relationship between general and domain-specific constructs is needed to

9. Since we also have a single item available on participants' general self-efficacy, we explored the possibility that this variable mediates the 2D:4D effect. Corresponding analyses, however, indicate that self-efficacy is related to entrepreneurial intent (Rauch & Frese, 2007) but not statistically significantly related to 2D:4D. This indicates that our risk measure does not spuriously pick up an effect of self-efficacy.

better link individual differences in biological and psychological differences to heterogeneity in entrepreneurial behavior. Omitting domain specificity of risk preferences might explain why general risk preferences have not always been found to affect selection into entrepreneurship (cf. Busenitz & Barney, 1997; Palich & Bagby, 1995). Applying the general-versus-specific argument to risk-taking, future research might be better equipped to identify effects of risk preferences on entrepreneurship.

Fourth, despite the exogeneity of a biological variable such as PTE or its proxy 2D:4D, these variables' relationships with entrepreneurial intent can still be spurious of socialization- and experience-related effects. Our related methodological discussion makes explicit the challenge that research differentiating biological from socialization effects is confronted with. While we statistically control for gender and parental self-employment, we are aware that these variables do not reflect all social mechanisms that may affect the observed relationship between 2D:4D and entrepreneurial intent. Future research might address this issue by identifying additional confounding social mechanisms or employ instrumental variable regression techniques to control for related biases.

Conclusion

Our study provides empirical evidence for a positive association between PTE and entrepreneurial intent. We identify a two-step indirect effect through general and domain-specific risk-taking, but also find indications of a possibly direct effect of PTE on entrepreneurial intent. We hope that our work stimulates future research that further elaborates on the role that PTE plays for selection into entrepreneurship, thereby carefully disentangling nature from nurture effects and searching for causal explanations that extend beyond mediation by risk-taking.

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