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Nothing Ventured, Nothing Gained:
Parasite Infection is associated with Entrepreneurial Initiation, Engagement and Performance

ABSTRACT

There is growing evidence that human biology and behavior is influenced by infectious microorganisms. One such microorganism is the protozoan *Toxoplasma gondii* (*TG*). Using longitudinal data covering the female population of Denmark, we extend research on the relationship between *TG* infection and entrepreneurial activity and outcomes. Results indicate that *TG* infection is associated with a subsequent increase in the probability of becoming an entrepreneur, and is linked to other outcomes including venture performance. With parasite behavioral manipulation antithetical to rational judgement, we join a growing conversation on biology and alternative drivers of business venturing.

Key words: entrepreneurship, entrepreneurial action, entry, persistence, venture performance, biology, *Toxoplasma gondii*, toxoplasmosis, parasite.

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INTRODUCTION

"We are all biological creatures and our biology affects all aspects of our behavior, including our work."
(Nofal et al., 2018: 22)

"Toxoplasmosis is one of the more common parasitic [infectious diseases] world-wide .... it has been estimated that up to one third of the world human population has been exposed to the parasite."
(Tenter et al., 2000: 1217)

Over the past decades, entrepreneurship scholars have made significant strides in enriching and advancing the understanding of business venturing. In addition to exploring how factors such as economics, policy and institutions relate to entrepreneurship (e.g., Busenitz, Gómez & Spencer, 2000), it is important to understand the individual-level drivers of venturing (Rauch & Frese, 2007; Hsu et al., 2017; van Gelderen et al., 2018; Zhang & Cueto, 2017). The entrepreneurial process starts with an individual and, "in the absence of action by individual entrepreneurs, there would simply be no entrepreneurship and no new ventures" (Baron, 2007: 167). Thus, it is not surprising that entrepreneurship scholars have drawn considerably on various psychology literatures (e.g. cognition, motivation, personality) to explain the individual differences that precipitate entrepreneurship.

Given the biological foundations of psychology and behavior, biology is arguably the ultimate micro-foundation of organizational scholarship. For example, recent research and theory suggests that entrepreneurship is, in part, predicted by: genetics (e.g. Nicolaou et al., 2008), hormones (e.g. Nicolaou, Patel, & Wolf, 2018; Bönte, Procher, & Urbig, 2016), psychophysiological system sensitivity (e.g. Lerner, Hatak, & Rauch 2018), and neurological conditions such as ADHD (e.g. Lerner, Verheul, & Thurik 2019; Wiklund, Patzelt, & Dimov, 2016). These and other studies indicate that the basis for venturing behavior extends well beyond traditional reason and judgment, and that theoretical frameworks for entrepreneurial action cannot rely exclusively on intendedly-rational logics (Lerner, Hunt & Dimov 2018; Hunt & Lerner 2018).

This reality might be most clearly demonstrated by recent work suggesting that a common parasite, *Toxoplasma gondii (TG),* known for its behavioral manipulation of warm-blooded animals, can impact human behavior including possibly in relation to entrepreneurship (Johnson et al., 2018).[1]

Our paper demonstrates that a microorganism known to biology, medicine, and psychology to alter host behavior – and which is one of the most prevalent infections in humans (Hill, Sreekumar, & Dubey, 2005; Tenter et al., 2000) – significantly relates to engagement and performance in business venturing. With *TG's* manipulation of human biology and psychology documented in the extant literature, our work serves as a basis for research on associated biological factors connected to venturing. Overall, the paper offers a bridge connecting biology and entrepreneurship – providing novel evidenced-based insight and perspective for theory building and refinement.

EXTANT LITERATURE AND GUIDING RESEARCH QUESTION

Most models of entrepreneurial activity and outcomes focus on economic, political, social, cultural, institutional or psychological variations among countries and individuals (e.g. Busenitz et al., 2000). However, recent evidence suggests that individual behavior may concurrently be influenced by independent biological agents including infectious microorganisms. Specifically the protozoan, *Toxoplasma gondii* (*TG*), infects an estimated two billion people worldwide and infection (toxoplasmosis) is linked to behavioral alterations in humans (e.g., Tenter et al., 2000; Webster, 2001).

[1] As individuals are apt to interpret and color their behavior *ex post* as intendedly-rational, particularly in relation to venturing, capturing non-rational drivers is often illusive (Hunt & Lerner 2018; Lerner et al., 2018a). Accordingly, assessing the potential effect of *TG* is ideal; the behavioral manipulation *TG* causes is quintessentially *not* rational for its host – but rather to increase the likelihood of intermediate host consumption (i.e. mortality) by a final host so the parasite can reproduce. Also, unlike a particular neurotransmitter, hormone, or other biological factor endogenous to an individual, *TG* is a biologically separate organism.

While the consideration of infectious microorganism parasites might on the surface seem odd to entrepreneurship scholars, there is increasing theoretical and empirical research linking such pathogen prevalence to individual human behavior; not only in medicine (Torrey & Yolken, 2003; Webster, 2001) and psychology (Schaller & Murray, 2008), but also in sociology (Fincher, et al., 2008) economics (Maseland, 2013), and more recently management (Houdek, 2017a). One example of such work is the examination of the behavioral manipulation parasites exert on their host due to changes in hormone and neurotransmitter functions (Houdek, 2017a; Lafferty, 2006; Torrey & Yolken, 2003; Webster, 2001). One example is *TG*. Because *TG* infection is permanent (there is no evidence that it can be cleared), infection rates can be quite high, exceeding 50% of the population in some countries (e.g. Tenter et al., 2000). Even among countries with the lowest infection rates (e.g. about 10% in Norway), its prevalence is noteworthy, and in excess of many other clinical conditions. Humans contract the parasite typically via eating the undercooked meat of an infected mammal or via exposure to the microscopic organism on inadequately washed food or hands (especially those in contact with cats) (Beverley, 1976; Lafferty, 2006; Webster, 2001).

TG and the behavioral effects of *TG* infection

TG, a protozoan organism, "is a ubiquitous parasite that occurs in most areas of the world" (Tenter et al., 2000). It is commonly found in cats and in many other warm-blooded animals (Dubey, 2014; 2016; Tenter et al., 2000). *TG* can only sexually reproduce in *Felidae* (cats) (Beverley, 1976); thus cats are considered *TG*'s final host. Like many parasites, its reproductive cycle involves moving to a final host via intermediary hosts (Tenter et al., 2000). In the case of *TG*, warm-blooded animals can serve as a possible intermediate; however, the most common intermediates are rodents and other small mammals. In an intermediate host, *TG* becomes dormant (latent); the infection subsides and the parasite forms cysts in the brain or muscle tissue of the host.

Only if an intermediary host (e.g. a mouse) is consumed by a cat can the parasite complete its reproductive cycle (Tenter et al., 2000).

Such life-cycles are common among parasites, with many having evolved to manipulate/alter the behavior of their intermediate hosts in a way that increases the probability of transmission to a final host (Moore, 2002). *TG* is no exception. *TG* has been shown to significantly alter the behavior of rodents in ways that increase the probability of transmission to (i.e. consumption by) domestic cats (Webster, 2001). For example, rodents with *TG* are more active (Hay et al., 1984), show elevated dopamine levels (Stibbs, 1985) – dopamine being a neurotransmitter known to increase novelty seeking behavior (Ebstein, 1996) – are more inclined to explore novel areas, and become less fearful of the smell of cats and cat urine, all of which increase the likelihood of being consumed by cats (Berdoy et al., 2000; Tan & Vyas, 2016).

As humans are warm blooded mammals, they can also be infected by *TG* (Dubey, 2014; 2016; Tenter et al., 2000). And just like in rodents, *TG* infections lead to behavioral changes in humans. The complexity of these changes are elaborated in other extant literature and beyond what we can engage in this paper; for recent reviews, see Houdek (2017a) and Flegr (2013). Here, we briefly overview how *TG* may alter human behavior before proceeding to our focal question of whether *TG* is linked to entrepreneurship entry and outcomes.

For a particular *TG* parasite, a human host typically represents a reproductive dead-end.[2] However, human brain chemistry is similar to that of other intermediary hosts, and thus, *TG* also exerts an influence on human host behavior. The infection-associated changes in the human brain are complex (Wang et al., 2015). Yet, in essence, *TG* infections lead to similar changes in humans as it does in rodents. In particular, *TG* has been associated with changes in the production,

[2] This has however not always been the case as in the past humans and our proto-human ancestors were preyed on by large cats and thus from the perspective of the evolution of *TG*, human hosts might have also played a role.

metabolism, and synthesis of hormones (e.g., testosterone) and neurotransmitters (e.g., dopamine, serotonin, and norepinephrine) in humans (Peng et al., 2018) which can create changes in personality. It has also been well established that the aforementioned effects are causally linked to *TG* infection, rather than the other way around (e.g. Torrey & Yolken, 2003).

TG and Business Venturing

Recently, the possibility of *TG* affecting behavior in – and relevant to – corporate settings has been suggested. In particular, Houdek (2017a) presents a comprehensive review of *TG*, elaborating the "physiological mechanisms of affecting the host; highlight[ing] important behavioral effects of the infection in humans; and speculat[ing] on the possible impacts on skills and careers of employees and managers, organizational dynamics, intercultural management, and gender work roles" (p63). Various complexities, and challenges to empirically studying *TG's* effect on vocational/organizational behavior and outcomes are further elaborated in an exchange that followed (see Flegr 2017; Houdek 2017b). These papers serve as a basis for further inquiry – providing an extensive review of *TG's* effect in humans and how it may affect vocational and organizational behavior in existing organizations. While these papers examine work related aspects of *TG* behavioral manipulations, they stop short of engaging aspects of entrepreneurship (i.e. entry into entrepreneurship, how individuals venture, and how their business ventures perform).

At present, there only appears to be one published paper that focuses specifically on *TG* and entrepreneurship: the paper of Johnson and colleagues (2018) which provides an initial empirical examination of a potential *TG*--entrepreneurship link. These authors found that among university students [Study 1], *TG* was positively linked to entry into the business school/major – and that within business students, *TG* was positively linked to an "entrepreneurship and

management" emphasis. In another cross-sectional study with a small non-representative sample of individuals attending an entrepreneurship event [Study 2], Johnson and colleagues (2018) found that an individual's *TG* status was able to discriminate the entrepreneurs (i.e. those self-reporting to have started a company) from the non-entrepreneurs. In other words, the findings of Johnson and colleagues' (2018) show *TG* infection is associated with an individual having a greater likelihood of being a business and particularly an entrepreneurship student – and may be positively connected to an individual actually venturing, based on the authors' exploratory study of individuals attending an entrepreneurship event.

However, there are at least two limitations of the work by Johnson and colleagues (2018) which we address. Their most important finding was that *TG* was positively related to an individual self-reporting of having started a business, in a small sample of people attending a local entrepreneurship event. In addition to the cross-sectional design limitation, that sample is far from random and consisted almost exclusively of men. Also, the work of Johnson and colleagues (2018) did not begin to examine how people venture or to what ends (entrepreneurial outcomes). Accordingly, additional research is needed with the prior findings providing a basis for inquiry.

In their paper, Johnson and colleagues (2018) argue that *TG* infection may relate to business venturing, due to a variety of behavioral manipulations, but especially because of the relationship between *TG* and risk-taking. They point out that *TG* has been associated with higher levels of testosterone in men and women (Zouei et al., 2018) – and prior research suggests that higher testosterone (measured as 2D:4D digit ratio) is associated with greater risk-taking and entrepreneurial intent in men and women (Bönte et al., 2016). In fact, *TG* is associated with a variety of human behaviors that are associated with a seeming increase in risk-taking behavior. For example, Samojłowicz and colleagues (2017) found a significant positive relationship between

infection and risky behaviors such as with not wearing a helmet during certain activities or with swimming while intoxicated. Infection has also been linked to car accidents in both men and women (Gohardehi et al., 2018). On the other hand, a study on a small sample of exclusively women did not find an effect of *TG* on financial risk-taking (Lanchava et al., 2015).

Findings in regards to *TG* and testosterone to date have also been mixed (Flegr, Lindová, & Kodym, 2008; Oktenli et al., 2004; Zouei et al., 2018). Specifically, the Flegr and colleagues study (2008) showed that testosterone was higher in *TG* infected men but lower in women, while the Oktenli and colleagues paper (2004) showed testosterone was lower in *TG*-infected men but did not test women. The most recent study, conducted by Zouei and colleagues in 2018 showed that testosterone was higher in both *TG*-infected men and women and they suggest that past discrepancies in research may be due to differences in the virulence of the strain of *TG* or in the stage of infection.

While any *TG*–venturing link might be connected to an increase in risk-taking typically associated with *TG* infection (Johnson et al., 2018), it might also be related to other manipulations of *TG*. For example, *TG* has been linked to higher extraversion among *TG*-positive men and women (Lindová et al., 2012), which could be associated with a greater tendency to engage with entrepreneurship, as entrepreneurs on-average tend to be more extraverted (Zhang et al., 2009). Other previous studies suggest that *TG* infection can result in lower conscientiousness (Flegr et al., 1996; 2000). This effect might decrease individuals' ability to work well as an employee, which might push them towards self-employment.

Thus, while links between *TG* and entrepreneurship can be speculated – there is a lot of complexity in both the effects of *TG* and in venturing – and empirical work involving both is extremely limited. Furthermore, independent of the particular causal mechanism, the pioneering

work of Johnson and colleagues (2018) simply finds evidence that *TG* infected individuals appear to be drawn towards business and particularly entrepreneurship, but does not examine any connection to how and how well individuals venture. Also, while appreciating their cross-sectional study with a small sample of individuals at an entrepreneurship event, the fundamental baseline question of whether *TG* is significantly linked to entrepreneurial entry/being an entrepreneur remains. Our paper contributes to filling these gaps.

In doing so we are guided by the entrepreneurship literature, which in addition to asking "who becomes an entrepreneur?" (Nicolaou et al., 2008: 7), is broadly concerned about the entrepreneurial process and outcomes (e.g. Aldrich & Ruef, 2018; Moroz & Hindl, 2012; Lerner, Hunt & Verheul, 2018; Shepherd et al., 2019). More specifically, in a recent review, Shepherd and colleagues (2019) find four general categories of dependent variables that are of central interest to the entrepreneurship literature: *initiation, engagement, performance,* and *environmental conditions*. Considering the early stage of research involving *TG* and entrepreneurship, we are interested in potential main effects of *TG* on individual actions and outcomes, and thus focus on the first three areas. In relation to these, Shepherd et al. (2019) note:

> "a common DV [dependent variable] is *entry*—undertaking organized activities—such as an individual's status as a self-employed person (Obschonka & Stuetzer, 2017)… Studies have also investigated team entry (Ruef, Aldrich, & Carter, 2003) … Research has also looked at reentry regarding subsequent new venture creation by individuals who become serial/habitual (Amaral, Baptista, & Lima, 2011) or portfolio entrepreneurs (Wiklund & Shepherd, 2008)" (p.165)
>
> "[Another] common DV [dependent variable is] *general firm-related performance* [which] include financial and economic performance outcomes, such as…earnings (Michael, 2003), [and] profits (Jacobides & Winter, 2007)" (p.175).

TG might affect these areas of interest to the entrepreneurship literature. However, as elaborated above, the effects of *TG* infections in human hosts are complex and are still being discovered in their details and interactions – especially in relation to vocationally situated behavior

spread across time and space. The antecedences of entrepreneurship are similarly complex; while some of the discovered *TG* behavioral manipulations are related, on average, to venturing (e.g. extraversion) others are more ambiguous (e.g. dopamine) or unclear (e.g. testosterone). Thus, given this complexity and considering the many tensions and dualisms within and across business venturing activities (Lerner et al., 2018b), we find an overly sparse basis from which to naturally develop a substantive and theoretically elaborated set of hypotheses about the effect and direction of *TG* behavioral manipulations on entrepreneurial activities. In addition, given the population-level longitudinal dataset (with individually linked records) available, we are not able to test particular mechanisms. Similarly, given the complex behavioral relationships, we cannot investigate the possible effects of all suggested behavioral consequences of *TG* infections. Accordingly, we can have a rigorous examination whether in fact *TG* is significantly associated with venturing (likelihood and outcomes) – with the tradeoff of not being able to examine (the causal pathways of) which particular *TG* behavioral manipulations seem to be responsible for observed effects. Thus, following the informed inquiry approach of the biological sciences, we abstain from formulating direct hypotheses, instead we engage a series of research questions.

Our questions are centered on a common scheme: given extant evidence of behavioral manipulations of *TG*, does *TG* infection affect venturing – namely, who ventures, how, and to what ends – i.e. entrepreneurial *initiation, engagement, and performance?*

Initiation: Following Johnson and colleagues (2018), who's cross-sectional work found a link between *TG* infections and selection toward entrepreneurship, *TG* infection might affect the likelihood of initiating one or multiple ventures. Thus, we ask:

> *Research Question 1a: Does TG infection affect an individual's subsequent probability of initiating a business venture – i.e. being an entrepreneur?*
>
> *Research Question 1b: Within entrepreneurs, does TG infection relate to an individual's probability of initiating multiple business ventures?*

TG might also affect how individuals initiate new ventures. Specifically, prior studies have found *TG* is positively related to increased neuroticism and aggression (e.g., Cook et al., 2015; Coccaro et al., 2016; Flegr 2007; 2016)[3] as well as to lower conscientiousness (Flegr et al., 1996; 2000); accordingly, it might be more difficult for *TG* positive entrepreneurs to collaborate with others, affecting the likelihood that they will found ventures alone versus with co-founders.[4] We therefore ask:

> *Research Question 1c: Within entrepreneurs, does TG infection affect the probability of founding alone?*

Engagement: TG might affect venturing persistence. On one hand, given the apparent linkages to entrepreneurial interest and activity in general (Johnson et al., 2018) and if *TG* is indeed linked to pursuing multiple ventures, entrepreneurs with *TG* might persist less with any given venture in favor of moving on to new entrepreneurial opportunities. Alternatively, the opposite might be the case. Considering the risks of venturing, especially the risk of persisting with a struggling potentially failing venture – if *TG* leads to increases in vocationally situated risk-taking – infected entrepreneurs might persist longer with a given venture than their uninfected counterparts. Thus, we ask:

> *Research Question 2: Within entrepreneurs, does TG infection affect an individual's persistence with a given venture?*

Performance: Given *TG*'s documented effects on human decision making and behavior (e.g. the potential for increased neuroticism and risk-taking, lower conscientiousness), it seems

[3] Cook et al. (2015) found increased aggression only in women (the effect in men was not significant), while Coccaro et al. (2016) found it in a mixed gender sample.
[4] This would seem consistent with Flegr (2017) who found a significant link between *TG* and number of subordinates, with *TG* infected men having less subordinates on average.

possible that *TG* infected entrepreneurs, relative to non-infected entrepreneurs, might show more variance in their behavior (e.g., be less stable and consistent). Thus, they might comparatively display more frequent changes in strategy or in the direction of a given venturing activity. Accordingly, *TG* might affect the variance in venture performance. We therefore ask:

> *Research Question 3a: Within entrepreneurs, does TG affect variance in venture performance?*

TG might also have a discernable effect on average performance. Entrepreneurship literature suggests that uncertainty (and risk) bearing are central to entrepreneurial profit (Knight, 1921; Townsend, Hunt, McMullen & Sarasvathy, 2018). In addition, entrepreneurial rents diminish over time on a given opportunity (e.g. Gavetti, 2012), and inertia and exploitation traps exist for initially successful ventures (Zahra, Sapienza, & Davidsson, 2006). Thus, if *TG* indeed leads to more variable or unconventional behavior and strategy, it might not only lead to more performance variance but also might ultimately increase overall performance. Separately, Lindová et al., (2010) showed that *TG* infected individuals may have an increased tendency of being generous which can be beneficial to form reciprocal relationships or might help in building entrepreneurial networks, either of which can help performance. Thus, *TG* might, *on-average,* be positively connected with venture performance.

On the other hand: unstable execution or excessive risk-taking can diminish performance per strategic mistakes (e.g., Denrell & Liu, 2012), or interfere with organizing and capturing value (cf. Lerner et al., 2018b). Similarly, other changes caused by *TG* infections such as increased neuroticism (Flegr, 2007; 2016) may have a negative effect on the ability of a given entrepreneur to successfully manage their venture. We thus ask:

> *Research Question 3b: Within entrepreneurs, does TG affect venture performance?*

METHOD

Data

Considering the central question of entrepreneurship (*who ventures and to what ends*), to examine the influence of *TG* on key entrepreneurship variables of interest (initiation, engagement, performance) and address some of the limitations of previous research, we utilize a large sample covering a large section of the entire population of Denmark. To conduct our analysis, we use two longitudinal datasets based on data made available by the Danish Statistics Bureau (DST). In particular, we leverage data of the DST on individuals and business firms, including data on new ventures with socioeconomic and health data of individuals.

Our first dataset is based on a sample of all ventures in Denmark[5] in the period 2005-2014. We draw on the Entrepreneurship Database (IVPE) which contains information on all new ventures and their founders, the Integrated Labor Market Database (IDA) containing employment data, the Firm Records Database (RAS) covering firm financial data, and the Medical Records Databases from hospitals, general and specialist physicians (SYIN/SYSI). This data is reliably connected through the unique social security numbers (CPR) and firm registration numbers (CVR) used throughout all public data in Denmark. For reasons later elaborated, we restrict our sample to women.

All new ventures founded in Denmark are recorded in the IVPE database. It is comprehensive as a VAT number and registration is necessary for any business transactions. Newly registered firms are defined as a new firm VAT registration in Denmark, which has not previously been registered under another owner, in another ownership structure or as a subsidiary of another firm or similar ownership. Only firms under private ownership are included.

[5] Not including the Faroe Islands and Greenland.

Government-, defense- or municipal-owned units, social clubs (including sports- and other leisure associations) or government supported firms are excluded from the IVPE. In addition, the IVPE only includes active firms with at least 0.5 person-years of work and/or with a non-trivial level of turnover (revenue). The turnover threshold is calculated based on the industry in which the firm is registered. New entries are recorded annually in IVPE, and surviving ventures from the prior year, providing clear entry and exit years from the dataset. A venture is only recorded as surviving if the activity threshold is met each year, inactive firms are removed.[6]

As it relates to data on *TG* and venturing, it is relevant to recognize the following. Since medical testing for *TG* is almost exclusively restricted to women during pregnancy, there is no representative data or systematic tests on the male population. Accordingly, we restrict our sample to childbearing women (women who were pregnant during our medical history sampling window, see below). While reducing sample size, this ensures near perfect fidelity in *TG* measurement, as all individuals should have been tested and thus an individual's *TG* status is actually known (i.e. ensuring a comparison of *TG*-positive individuals versus *TG*-negative individuals, rather than versus the combined pool of *TG-negative* and *TG-unknown*). Overall our data covers 11,433 ventures, founded by 16,068 women. Of these, 1,831 are *TG*-positive. The mean persistence with a venture is 4.1 years, and about half the ventures in the dataset are co-founded.

We observe the economic activities of individuals from 2005 to 2014, and their medical history from 1995 to 2014. Summary statistics and pairwise correlations are later presented.

To investigate Research Question (RQ) 1a, of whether *TG* infection affects an individual's subsequent likelihood of initiating business venturing (i.e. being an entrepreneur), we also use a second *non-entrepreneurship* dataset. This dataset is based on a random sample of a fifth of the

[6] The criteria for active firms are determined by the data provider, DST, prior to the data being made available to us.

population working in private enterprise, provided by the DST.[7] To ensure the comparison is based on actual *TG* (*positive* versus *negative*) status, we again restrict the larger sample to females with children. This reduced sample contains a total of 58,223 women, of which 5,362 are *TG-positive* and the remaining *TG-negative*. The employment and health data for this sample is collected from the same databases, as used for the sample of entrepreneurs, covering the same period of time.

Dependent Variables:

We developed a set of dependent variables to investigate the effect of *TG* on venture *initiation, engagement,* and *performance.*

To capture aspects of venture initiation (RQ 1a, 1b and 1c) we test if individuals with *TG* are more likely to become entrepreneurs, if they are more likely to start multiple ventures, and if they are more likely to found solo or with a team. We use the following variables:

Entrepreneur: Whether an individual (woman) is an entrepreneur, i.e. has founded a venture in the year of observation. The variable takes the value of 1 if yes, and 0 if not.

Serial Entrepreneur: Whether an entrepreneur has founded more than one venture. The variable takes the value of 1 if yes (i.e. if the number of new ventures founded by the individual is >1), and zero if not.

Solo venture [sole founder]: Whether the venture is founded by a single individual at the time of inception. The variable takes the value of 1 if yes, and 0 if not. Should the ownership structure change after founding, the value of this variable does not change.

In terms of venture engagement (RQ 2) we test if *TG* positive entrepreneurs are more or less persistent with a given venture than non-infected entrepreneurs, using the following variable:

[7] The sampling was completed by DST, randomly selecting individuals from the total population, following the gender and employment criteria.

Venture persistence: This is captured as the number of years the founder stays with the venture. Persistence might end due to termination of the venture, selling the venture, or leaving the venture for other reasons.

In terms of venture performance (RQ 3a and 3b), we test if the performance as well as the performance variance differs between *TG* positive and *TG* negative entrepreneurs, with the following variables:

Venture Performance: We compute the average yearly entrepreneurial earnings for each entrepreneur following an adaptation of Hamilton's (2000) specification: *entrepreneurial earnings = draw (money withdrawn from the business as salary by the entrepreneur) + retained earnings for each year* (this is equivalent to the firm's profits (revenues - expenses)). Entrepreneurial earnings serve as a proxy for the financial performance of the venture.

Performance Variance: To compute the variation in performance, we rely on entrepreneurial earnings, as described above, and the longitudinal nature of the dataset. This is computed as the standard deviation of the entrepreneurial earnings for each venture.

Independent variables:

TG: This is our focal, independent variable. It is a dichotomous variable indicating whether an individual (woman) has been diagnosed as *TG* positive or negative prior to the year of observation. While *TG* can be diagnosed in multiple ways in Denmark, the most common method is for the test to be administered during pregnancy. We rely on diagnostics data from both hospitals, as well as general and specialist physicians. Hospital diagnostics are recorded using the International Classification of Diseases (ICD), in which *TG* is classified with the category *B58*. We include individuals with a diagnosis in this category as *TG* positive. In addition, *TG* cases are also diagnosed by general physicians as part of standard tests during a pregnancy. These are not

classified with ICD, but rather through the general medical records under which a *TG* specific diagnosis exists.

Control variables:

To help assess the effect of *TG* in relation to the focal research questions, we include the following control variables about the individuals in our dataset:

Age: We control for the age of the individual. Prior research has shown age to be a strong predictor of entry into entrepreneurship (Berglann et al., 2011). Age is measured in years.

Age squared: We include the squared term of age in our models to control for a potential non-linear relationship between entrepreneurial activities and age (Dvouletý, 2018; Simoes, Crespo, & Moreira, 2016).

Marital status: Indicating whether the individual is married or in a registered partnership, or not. The variable takes the value of 1 if yes, and 0 if not. Prior research suggests that women, more so than men, are motivated to enter into entrepreneurship for family-related lifestyle reasons (DeMartino & Barbato, 2003), of which marriage can be a strong predictor – as well as number of children, for which we also control.

Children: The number of children the individual has.

Education: The level of highest completed education, using single digit ISCED codes. This ranges from no formal schooling (0) to doctorate level (8). This adjusts for level of education potentially affecting vocational choice and venturing outcomes (Van der Sluis & van Praag, 2004).

Medical history: This variable is included to control for general health; in essence, it helps ensure that an apparent effect of *TG* is not simply an effect of (poor) general health driving someone into entrepreneurship. We use the number of interactions an individual has had with the medical system since 1995. This variable records the number of total interactions. The purpose of

this variable is to proxy the general health level of the individual. Note that an interaction can range from complex surgery, to a simple phone consultation, and thus some individuals can have a high number of interactions. While each interaction is not equal in terms of severity (e.g. *malignant tumor removal* versus *annual check-up*), a serious medical condition or procedure will involve multiple interactions for diagnosis, treatment, evaluation and so forth, thus a count of interactions proxies overall health well.

In relation to venturing performance and persistence, we also include the following:

Geographical location: To control for regional differences that may affect both *TG* infection and/or entrepreneurial activity and outcomes, we introduce fixed effects for the five regions of Denmark, based on the NUTS level 2 regional codes (we also test Danish provinces, of which there are 11, as an alternative with almost identical results).

Venture size: The size of the venture measured in number of employees.

Venture turnover (revenue): Another size related control, turnover of the venture measured in 1,000 DKK, transformed logarithmically due to the highly skewed distribution of turnover.

Venture exports: Exports of the venture measured in 1,000 DKK, again transformed logarithmically. Due to the small size of the Danish economy, and general reliance on international trade, exports are an additional control for a venture's size and sophistication.

Summary statistics of our dataset of entrepreneurs are shown in Table 1. Pairwise correlations follow in Table 2.

Table 1 - Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Venture performance	16,068	168,099	217,481	0	17,668,178
Performance variance	16,068	-25,448	187,458	-87,912	1,328,869
Solo venture (sole founder)	16,068	.472	.277	0	1
Serial entrepreneur	16,068	.109	.312	0	1
Venture persistence	16,068	4.098	2.748	1	11
TG	16,068	.114	.207	0	1
Age	16,068	39.323	7.119	18	65
Marital status	16,068	.333	.471	0	1
Education	16,068	3.952	1.885	0	8
Children	16,068	1.879	.824	1	9
Medical history	16,068	288.052	183.819	0	4908
Venture size	16,068	1.236	2.221	1	111
Venture turnover	16,068	12.920	3.122	0	19.690
Venture exports	16,068	9.094	5.945	0	19.560

Table 2 - Pairwise correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	**Venture performance**													
2	**Performance variance**	-0.420												
3	**Solo venture**	-0.020	-0.014											
4	**Serial entrepreneur**	-0.062	0.077	0.167										
5	**Venture persistence**	0.008	-0.018	0.096	0.084									
6	***TG***	-0.025	0.010	0.016	0.010	-0.030								
7	**Age**	0.074	0.038	-0.034	0.023	0.021	-0.099							
8	**Marital status**	-0.009	-0.001	0.019	0.001	-0.052	0.003	-0.138						
9	**Education**	0.107	0.033	-0.034	0.010	0.002	0.056	0.172	-0.074					
10	**Children**	-0.043	-0.017	-0.008	-0.007	-0.006	-0.001	-0.069	-0.194	-0.015				
11	**Medical history**	-0.005	-0.007	0.001	0.015	-0.110	0.044	0.147	-0.004	0.026	0.081			
12	**Venture size**	0.008	0.016	-0.011	0.070	0.130	-0.017	0.011	-0.023	-0.060	0.004	-0.012		
13	**Venture turnover**	0.002	-0.028	0.009	-0.019	0.073	-0.016	-0.031	-0.027	-0.061	0.017	-0.026	0.165	
14	**Venture exports**	0.019	0.001	-0.003	0.079	-0.058	-0.011	-0.028	0.010	-0.181	0.035	0.056	0.090	0.334

Analytical Approach

Our models are estimated using the STATA statistical package. The logistic regression models are estimated in two steps. First, we derive the regression coefficients using the *logit* command in STATA. Second, to also offer more interpretable results, we additionally estimate the corresponding odds ratios using the *logistic* command.

The first model tests whether being *TG*-positive increases the likelihood of subsequently becoming an entrepreneur (RQ 1a). This is a logistic regression model with the dependent variable indicating whether or not the individual (woman) becomes an entrepreneur in the year of observation. We use our full sample of childbearing women, covering both entrepreneurs, and non-entrepreneurs. This ensures that all individuals have been tested for *TG*, removing false negatives from the sample. The data is organized in an unbalanced panel, allowing us to accurately record whether the individual was diagnosed as *TG* positive at the time of the start of any given venture.

The second and third models test the relationship between *TG* and the propensity of entrepreneurs to found multiple ventures (RQ 1b) and to start a venture alone (RQ 1c). The fourth model tests the relationship between *TG* and the propensity of entrepreneurs to persist with a venture (RQ 2). As these questions are limited to "within entrepreneurs…", we use the entrepreneur sub-set of our initial sample. The data is again organized in an unbalanced panel to correctly estimate the effects of *TG*. An individual is only considered *TG* positive if they were diagnosed *prior to* the recorded venturing event.

The fifth and sixth models test whether ventures founded by individuals with *TG* perform different in comparison to ventures founded by individuals without *TG* (RQ 3a and RQ 3b). The dependent variable used are integer variables, the earnings of the venture and the standard deviation of these earnings. As such we employ an ordinary least squared (OLS) approach. These

analyses use the entrepreneur (sub)sample described above for the second through fourth model. The data is tested for normality using the Shapiro-Wilk test (Greene 2011), multicollinearity using the variance inflation test, and heteroskedasticity using the Breusch-Pagan test (Wooldridge 2004). The tests show no issues of breaking the assumptions of the OLS model.

RESULTS

Our results are summarized in Table 3. As previously noted in regards to the longitudinal data, and later discussed, the results are based on representative samples of the female population of Denmark. The first model estimates the relationship between *TG* and the probability of being an entrepreneur (RQ 1a). Comparing entrepreneurs to non-entrepreneurs from the control sample shows a significant, positive relationship between *TG* (*.683***) and the probability of the individual to enter into entrepreneurship. We calculate an odds ratio of 1.292, finding that *TG* positive individuals are 29.2% more likely to subsequently enter into entrepreneurship compared to *TG* negative individuals.

The implications of *TG* on how entrepreneurs venture, and to what ends, are tested in the remaining models. In these models we only included individuals who started at least one venture. In the second model we find that *TG* has a positive, significant relationship (*.303***) with the likelihood of an individual entrepreneur founding multiple ventures (RQ 1b). Calculating an odds ratio of 1.266, we find that *TG* positive individuals are 26.6% more likely to found multiple ventures, compared to *TG* negative individuals. In the third model we test whether entrepreneurs with *TG* are more likely to found a venture alone, rather than with co-founders (RQ 1c). We find a positive, significant relationship (*.852***) between *TG* and the probability of the venture being founded by a single individual. With a calculated odds ratio of 2.344, we see that individuals

diagnosed with *TG* are more than twice as likely (specifically, 134% more likely) to start a venture by themselves, compared to individuals without *TG*.

In the fourth model we find that *TG* has a significant and negative relationship with an entrepreneur staying with her venture (*-1.171****) (RQ 2). This, on average, corresponds to a shortening of an entrepreneur's persistence by about 1.1 years for *TG* positive individuals. The mean venture persistence across all observations is 4.09 years. Thus, *TG* appears to reduce persistence with a venture by about 25% from the mean value.

The next models examine the implications of *TG* for the performance of the venture. Model five tests the relationship between *TG* and the variance in venture performance (RQ 3a). We find a positive, significant relationship (*40,489.86****) between *TG* and *Performance variance*, showing a higher fluctuation of performance amongst ventures founded by individuals with *TG*. This corresponds to a higher standard deviation in performance annually of 40,489 DKK (roughly 6,000 USD) for ventures founded by *TG* positive individuals. Model six tests the relationship between *TG* and venture performance (RQ 3b), finding a positive, significant relationship (14,689.89**). This shows that not only do the ventures of *TG* positive entrepreneurs have a higher variation in performance across time, but also exhibit a higher general level of performance on aggregate. This corresponds to 14,690 DKK annually in increased performance (roughly 2,200 USD). This corresponds to about 8% of the mean value of the performance variable, and about 7% of the standard deviation.

Table 3 - Logistic and OLS regressions

	Model 1 (RQ 1a)	Model 2 (RQ 1b)	Model 3 (RQ 1c)	Model 4 (RQ 2)	Model 5 (RQ 3a)	Model 6 (RQ 3b)
Estimation method[a]:	Logistic regression	Logistic regression	Logistic regression	OLS regression	OLS regression	OLS regression
Dependent variable:	Entrepreneur	Serial entrepreneur	Solo venture	Venture persistence	Performance variance	Venture performance
TG	.683 ***	.303 ***	.852 **	-1.171 ***	40,489.86 ***	14,689.89 ***
	(.179)	(.047)	(.481)	(.004)	(2,101.67)	(4,345.27)
Age	.087 ***	.092 ***	.116 ***	.316 ***	-1,027.59 ***	4,439.82 ***
	(.018)	(.026)	(.046)	(.016)	(68.11)	(176.52)
Age squared	-.001 ***	-.001 ***	-.002 ***	-.004 ***	632.67	-127,12 *
	(.000)	(.000)	(.000)	(.000)	(899.21)	(26.23)
Marital status[b]	.118 ***	-.047	-.121	.262 ***	-2,423.54 **	-2,125.18
	(.033)	(.044)	(.079)	(.038)	(1,067.17)	(2,955.61)
Education	.021 ***	.004	-.094 ***	.011	11,436.67 ***	21,314.66 ***
	(.008)	(.011)	(.020)	(.009)	(308.60)	(781.45)
Children	-.029	-.018	-.069	-0.15	-2,959.11 ***	-1,749.38
	(.019)	(.026)	(.045)	(.020)	(585.04)	(1,412.59)
Medical history	.000 ***	.008 ***	.000 ***	-.001 ***	2.67	-14.82 **
	(.000)	(.000)	(.000)	(.000)	(2.61)	(6.57)
Serial entrepreneur[b]			1.717 ***	.606 ***	24,913.61 ***	3,166.62 **
			(.074)	(.061)	(2,252.06)	(541.67)
Venture size				.134 ***	499.54 ***	1,525.02 ***
				(.014)	(210.57)	(558.72)
Venture turnover				.047***	459.27 ***	1,497.77 ***
				(.005)	(185.30)	(516.91)
Venture exports				-.011 **	1,085.78 ***	561.72 **
				(.006)	(293.14)	(71.74)
Location dummies[b]	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Cragg & Uhler's R^2	0.1891	0.2207	0.1812			
R^2				0.1499	0.2660	0.1845
Chi squared	211.06	314.76	429.35			
F-value				108.23	217.30	223.42
Observations	74,291	16,068	16,068	16,068	16,068	16,068

Notes: *** p < .01, ** p < .05, * p < .10

a: Coefficients reported for both Logit and OLS models. (Odds ratios for *TG* are reported in the body text.)

b: Reference categories for dummy variables: Marital status: 0 is not married; Serial entrepreneur: 0 is not a serial entrepreneur; Location dummies: 0 is the capital region (DK01); *TG* status: 0 is no latent *TG* infection.

SENSITIVITY ANALYSIS

To test the robustness of our findings, we perform a number of additional analyses. First, all models are estimated using an alternative dependent variable. In the main models *TG* is used, which indicates whether the individual has been diagnosed as *TG* positive at any time (within our dataset window) before the focal year of observation. To test the sensitivity of our analysis to time, we repeated all models using *TG*5 as the dependent variable. This is constructed similarly to the *TG* variable, however with the restriction that for *TG5* the woman had to be diagnosed with *TG* within the past five years before the focal year of observation. Five years are used due to the diagnosis predominantly being made early during pregnancies, and thus to ensure a sufficient window of measurement in which the woman can return to the labor market, potentially start a venture, and allow the venture to exist long enough to create a record in the labor market data. These analyses test the effects of *TG* infection in a temporally more proximal way. We find highly similar results, and while the magnitudes of the coefficients change slightly this does not change the significant levels of any results.

We further tested our results in regards to RQs 1b, 1c, 2, 3a and 3b using a matched sampling approach. We employed propensity score matching on age, education, marital status and number of children, matching *TG* positive entrepreneurs to *TG* negative entrepreneurs. Note that due to these variables being used in the matching procedure, they lose their significance when compared to our non-matched models. This setup allows for a direct comparison of *TG* positive to *TG* negative individuals, while retaining a similar socioeconomic level. Broadly our results are similar when applying this approach, however due to the restrictive nature of the sampling method, some odds ratios and effects are reduced slightly in magnitude.

International travel might expose individuals to entrepreneurial ideas but also increase the likelihood of *TG* infection, as infection rates differ by country. Accordingly, we conducted a sensitivity analysis in which we try to control for this aspect. While all travel might expose individuals to entrepreneurial ideas, not all locations will, at the same time, increase the possibility of *TG* infections (e.g. Norway or the UK for example have respectively lower and similar *TG* prevalence rates as Denmark). Yet, *TG* rates are on average higher in tropical locations. Thus to control for the possibility of foreign travel causing issues, we included the number of prescriptions for malaria prevention medication received (as such medication is often taken by travelers to tropical countries). Including this as a control variable does not alter the results of our estimations.

We also tested our results adding individuals diagnosed as *TG* positive, without having been pregnant, to our sample. *TG* diagnostics are not common outside of pregnancies, however in some cases individuals are being diagnosed as *TG* positive. This supplemental analysis does not change our estimations discernably.

We also considered the fact that *TG* infections can be fatal in individuals with compromised immune systems (Innes, 2010), thus we performed a sensitivity analysis excluding all individuals registered as a mortality case at any point in our data. We identified 21 mortality cases among the sample of women entrepreneurs, and 109 cases in the full sample of women entrepreneurs and non-entrepreneurs. Omitting these observations from our data does not influence our estimates. In addition, we also compared the mortality rate in our sample with that of the general population, during the same period of observation and age group. We find the mortality rate of the women in our data is very low (0.13%), and does not suggest potential mortality bias. In fact, the mortality rate in our sample is lower than the national average (0.23%) for women in the same age groups, and similar to the national average of women employed in private enterprise only (0.14%).

Finally, we tested the robustness of our results in terms of age by considering the age of the woman when giving birth. We removed individuals from the sample who only had children prior to legal age (18 years), which is the required age for registering a firm. Adding either of these individuals to our sample does not influence the results, and our findings remain robust. These models are all available upon request from the authors.

DISCUSSION

Our study of 11,433 ventures, founded by 16,068 individuals (women), with another 58,223 non-entrepreneurs (women) in the control sample supports multiple links between the highly prevalent parasite *Toxoplasma gondii* and entrepreneurship. Although the possible association has been previously proposed, our extensive longitudinal data and large sample offer an important replication and extension of Johnson and colleagues (2018) and add to other recent work suggesting connections to organizational behavior and management (Houdek, 2017a/b; 2018; Flegr, 2017). Building on and extending extant literatures, we find that a *TG* infection is associated with a higher likelihood of subsequently becoming an entrepreneur. Moreover, based on the population-level longitudinal dataset, we are able to explicitly observe that *TG* infection *precedes* venturing. Specifically, based on our regression results, we can say that *following TG infection, individuals (women) are significantly more likely to venture*. This effect is robust across our analyses. Overall, we observe that those with latent *TG* infections are 29% more likely to subsequently enter into entrepreneurship compared to those without *TG*.

Furthermore, we look beyond the propensity to enter entrepreneurship, and start to examine the relationship between *TG* and venturing behavior/how individuals' venture. In particular, our findings show that *TG* infection is associated with an increase in the likelihood of serial entrepreneurship and of solo ventures (being a sole founder), and with decreased average

persistence with any given venture. Additionally, we break ground in examining the relationship between *TG* and venturing outcomes. Our results indicate a relationship between *TG* and venture performance. Specifically, we observe that entrepreneurs with *TG* show more variant venture performance[8] – and that *TG* is associated with a positive overall effect on venture performance.

We recognize that similar to other large-scale studies of biological factors influencing venturing (e.g. Nicolaou et al., 2008), there are inherent unescapable tradeoffs related to the empirical optics and aperture possible. While capturing the granular entrepreneurial behaviors and dynamics of PSED-type studies (e.g. Reynolds & Curtin 2009) would be interesting, it is not realistic for epidemiological and population-level inquiries. Similarly, the large-scale surveying of the individuals in the overlaid health-records and other government records datasets – for example to collect empirical measures of likely mediators (e.g. risk-taking, personality) or potential contextual moderators – is neither realistic nor even possible due to data-access and confidentially restrictions. Nonetheless, our large-scale uniquely comprehensive longitudinal datasets include fine-grained data, linked to a specific individual for over a decade. Furthermore, unlike data that subject to sampling (e.g. winners') or other biases (entrepreneur self-report), the data is based on the population of a country and representative in the venturing it captures (e.g. Aldrich & Ruef, 2018). As such, the study offers a unique and solid basis for testing the connection between *TG* infection and entrepreneurship.

Theoretical Implications

There are various theoretical implications of our work. Generally, our work substantiates the importance of biology and biological agents in entrepreneurship theory. There is already

[8] This might also be connected to the finding of venture persistence. To the extent that a newly founded firm is resource scarce, with greater variance in venture earnings, *TG* positive entrepreneurs are apt to have a higher chance to hit a particularly bad year in which they run out of resources and the venture ends.

evidence of the relevance of hormones and neurotransmitters to human behavior and venturing (Bönte et al., 2016; Nicolaou et al., 2008; Nicolaou et al., 2018). *TG* is relevant to such theory, as the very mechanism through which it affects its host is through the manipulation of host brain chemistry (Houdek, 2017a). Additionally, since *TG* affects a host's decision-making and personality (Houdek, 2017a), our work has implications for advancing and reenergizing associated entrepreneurship theory (Rauch & Frese 2007; Obschonka & Stuetzer, 2017; Zhang & Cueto 2017). Bridging the two, *TG* can help connect biological and psychological perspectives/theories.

The antecedents of entrepreneurial initiation, engagement and performance are central to entrepreneurship theory (e.g., Shepherd et al., 2019); a theoretical contribution of our work is opening an entirely new realm of unstudied influence – exogenous biological agents, specifically parasitic manipulation. When thinking of the biological basis of entrepreneurship we often think of characteristics of the human being; yet for example, bacteria and protozoa (i.e., foreign entities living off or with us) comprise a large portion of cells in the human body, making it essential to explore how these organisms impact human behavior (Proctor, 2011; Johnson & Johnson, 2018). Parasites, diseases, and microbiota can have vast influences on psychological factors like impulsivity, dominance, empathy, and mental illness (Houdek, 2017a; Kramer & Bressan, 2015). As Houdek (2017a) elaborates, personality changes associated with *TG* infection are mediated by hormonal or neurotransmitter changes and can have important effects on vocational and organizational behavior. Adding entrepreneurial behavior is an additional important consequence of a parasite infection. Thus, this paper contributes to the small but growing field of parasite-psychobiology (Johnson & Johnson, 2018).

While certainly further research is required, the observed positive connection between *TG* and venture performance is intriguing. With *TG* having evolved to impair prudent perception and

behavior of intermediary hosts, one could certainly imagine that *TG* might undermine effective entrepreneurial decision-making and performance. But, in the realm of entrepreneurship – where risk and uncertainty are unavoidable – the negative tradeoffs of *TG* might be offset or even eclipsed by the volatile yet ultimate returns associated with disinhibition and the increased bearing (or even seeking) of entrepreneurial uncertainty and risk. This could explain the positive association between *TG* with both performance variability and overall mean performance.

Concurrently, there might be various other underlying reasons for the found connection between *TG* and entrepreneurship; independent of the particular causal mechanism, the robust results from our longitudinal population-level dataset suggests that further research is indeed warranted (e.g., to elucidate the mechanisms, practical implications, etcetera).

The findings are consistent with a recent and growing perspective in the entrepreneurship literature that challenges the underlying premise of reasoned judgment and intendedly-rational logics. In particular, this paper's thesis and results fit with recent work suggesting alternative drivers of entrepreneurial action – such as disinhibition (Lerner 2016; Lerner et al., 2018a/b), impulsivity (Wiklund et al., 2018a), and conditions such as Attention-Deficit/Hyperactivity Disorder (Lerner et al., 2019; Verheul et al., 2016; Wiklund et al., 2016; 2017).

With *TG* being an exogenous biological agent and antithetical to rational judgment, the work contributes to general entrepreneurship theory. The work does so by unambiguously evidencing that the basis for entrepreneurial action and outcomes is not limited to the reasoned or even conscious. While we absolutely do not question reasoned judgment is important to venturing, our work attests to the fact that for veridical entrepreneurship theory, theoretical foundations and frameworks must accommodate biological and other non-reasoned underpinnings (Nofal et al., 2018; Hunt & Lerner 2018; Lerner et al., 2018a; Nicolaou et al., 2008; Wiklund et al., 2018b).

Furthermore, since entrepreneurship research has only recently begun to consider the latter, our study suggests the need and opportunity for considerably more research on biological and related factors in this regard.

Generalizability, Limitations, and Future Research

In regards to generalizability, it is important to bear in mind a number of things. The purpose and contribution of our paper is *not* to derive generalizable parameter estimates; rather it is in assessing if there is evidence of a positive linkage between a known biological agent (*TG*) and entrepreneurial entry behavior and outcomes. The longitudinal design – supported by comprehensive, systematic, population-level data, derived from objective medical records and legally required business-related filings spanning over a decade – offers a remarkable basis for such assessment.

Relatedly, it is important to recognize that our empirical context was limited to women in Denmark, primarily those who had been pregnant and thus tested for *TG*. Delimiting to a single country is something of trade-off; it is a strength as it provides a focused examination of the fundamental research questions within a specific and stable common context. Additionally, especially when considered in the context of separate findings positively linking a nation's *TG* rate with national-level entrepreneurship activity and attitudes across 42 countries (Study 3 of Johnson et al., 2018) and the positive individual-level connections found in the United States (Studies 1 and 2 of Johnson et al., 2018), there is no likely reason the general relationships we observed should not generally apply elsewhere. Nonetheless, studies in other nations would be beneficial, and generalizing our parameter estimates or effect sizes would *not* be appropriate.

The fact that comprehensive data were only available for women raises additional concern, as past research has shown different behavioral correlates of *TG* for men and women (Flegr, 2013

for a review). For example, some studies suggest that *TG* is associated with increased testosterone in male humans (or male rats) but not in female humans or castrated male rats (Flegr et al., 2008; House et al., 2011; Lim et al. 2013). In contrast, more recent research has demonstrated that *TG* infected men *and TG* infected women had significantly higher levels of testosterone than uninfected controls (Zouei et al., 2018). Given that testosterone is implicated in increased risk-taking (Hermans et al., 2010), it is important for future research to examine the role of sex and testosterone in understanding the *TG*–entrepreneurship link.

In addition to potential differences in hormone responses to *TG*, or maybe because of them, Flegr shows that different personality factors are associated with *TG* infection in men and women (see Flegr, 2013 for a review). Yet, there is some evidence of consistent personality correlates of *TG* in men and women such as extraversion (Lindová, Příplatová, & Flegr, 2012) and extraversion is positively related to entrepreneurship (Zhang et al., 2009). The gender difference problem is further exacerbated by the fact that men and women are socialized to deal with stressors in different ways; men tend to respond to stress with problem-focused coping and women engage in more relationship-focused coping (Lindová et al., 2006, Lindová et al., 2010). In the context of entrepreneurship, we might see differences in reactions to venturing stressors. The effects of *TG* may also differ depending on the individual's Rh blood group, further complicating the question (Flegr et al., 2013; Novotná et al., 2008; Šebánková & Flegr, 2017).[9]

In sum, past studies suggest that there are a variety of ways in which men and women can differ in terms of how they respond to *TG*, which in turn could relate to entrepreneurship. Because the current study only included women and it was not possible to measure hormones or personality, we cannot be sure that the findings for *TG* infected men would be the same (greater probability of

[9] We recognize helpful reviewer comments in relation to this and a number of preceding points.

starting a venture, starting multiple ventures, and starting solo ventures; lower persistence with a given venture; higher performance variability and overall higher performance). That being said, in the one previous inquiry into *TG* and entrepreneurship, the multiple studies of Johnson and colleagues were based on both sexes and showed no sex differences (Johnson et al., 2018). This lends confidence to our findings that *TG* positive individuals are more likely to engage in entrepreneurship, but does not allay concerns in relation to whether our findings on the link between entrepreneurship and the other outcomes, such as venture performance or persistence can be generalized to all humans (men and women), opening the door for multiple opportunities for future research in this area.

In addition, the behavioral effects we discuss are only the tip of the iceberg; they serve to motivate our research, but given the complexity of *TG* in humans, other mechanisms might also contribute to the observed effects. In this regard, we want to clearly acknowledge that the intended contribution of our research is *not* to provide a highly specified extension of the *TG* literature; our study by design cannot test the underlying behavioral manipulations of *TG* nor can we explain which behavioral manipulations cause the found effects. Rather, the contribution of our study as it relates to *TG* is in evidencing that there are general significant linkages to venturing, and thus that there is the need and opportunity for continued/future research.

Overall, given the state of knowledge, our contribution is in powerfully examining whether there is an observable significant relationship between *TG* and venturing. The evidence, based on a level of data rarely seen in entrepreneurship studies, offers a clear answer. Furthermore, the work offers evidence of a solid empirical basis for subsequent research. The findings support that further study is warranted, for example, sampling other populations, assessing the particular mechanisms or fine-grained dynamics at hand, or examining the influence of contextual factors.

Conclusion

This paper extends research considering biological underpinnings of entrepreneurship, and research considering the effects of *TG* infection – a condition estimated to affect a third or potentially more of the world population (Tenter et al., 2000). Based on epidemiological data covering over 15 years and objective business data representatively sampling an entire female population for an entire decade, a longitudinal link between an individual's *TG* infection status, entrepreneurship entry and performance was observed. The findings highlight the potential, and need, to consider biological factors beyond the conventional. More broadly, the work contributes to theory on entrepreneurial action and outcomes. As there could seemingly be nothing more aberrant and antithetical to rational reason than parasite behavioral manipulation, it joins the growing conversation on the existence of alternative individual-level underpinnings to venturing (Lerner et al., 2018a; Wiklund, 2019; Hunt & Lerner 2018).

Given *TG*'s ubiquitous presence and linkages to myriad adverse outcomes (Flegr et al., 2014), the positive linkages to venturing are noteworthy.[10] Beyond adding to the current *TG* literature and to the general epidemiological literature, the fact that a "public health hazard" (Flegr et al., 2014: 1) parasite is positively linked to venturing, supports there is some uncommon/special/aberrant about entrepreneurship, which provides a basis and opportunity to develop and advance new theory (Miller & Le-Brenton-Miller, 2017; Lerner et al., 2018a). Finally, with *TG*'s manipulation of human biology and psychology documented in the extant literature, the work serves as a basis for future research on associated biological factors (e.g., dopamine, testosterone) connected to venturing (Nofal et al., 2018).

[10] Especially given the adverse consequences of *TG* infection, it is important to underscore this absolutely *does not* (and should not be interpreted to) offer any normative suggestions.

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