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E X C H A N G E

DO *TOXOPLASMA*-INFECTED SUBJECTS HAVE BETTER LEADERSHIP SKILLS? COMMENT ON PAPER "PUPPET MASTER: POSSIBLE INFLUENCE OF THE PARASITE *TOXOPLASMA GONDII* ON MANAGERS AND EMPLOYEES"

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Houdek (2017) performed a thorough literature survey to demonstrate that latent infection by protozoan parasite *Toxoplasma* could have specific effects on personality traits and cognitive performance. These effects could, among other things, influence an infected individual's career outcome, as well as the inner workings of teams and firms. Based on published data on specific *Toxoplasma*-associated behavioral changes, he made several predictions concerning possible impacts of *Toxoplasma* infection on the career outcome of affected persons. Most of the suggested impacts are negative, however, some predict possible positive effects of the infection on the career outcome. Later hypotheses are rather contra intuitive and 'sexy', and therefore they have a potential for attracting the attention of the professional as well as the general audience. Houdek suggests, for example, that due to an increased concentration of testosterone leading to higher masculinity and dominance, the infected men could have better leadership skills and executive abilities. This conclusion, however, appears to contradict an anecdotal observation published in the first paper reporting the behavioral effects of toxoplasmosis in humans (Flegr & Hrdý, 1994). It was mentioned there that among the professors of the Faculty of Science, Charles University, out of 29 members that were *Toxoplasma-free,* 10 were members in senior positions (heads of department, vice-deans, and deans). In the same study, out of 14 *Toxoplasma*-infected members, only one subject was the head of a department. Houdek is aware about the probable transient nature of increased level of testosterone, as well as about cumulative nature of many negative effects of toxoplasmosis. Therefore, he suggests that positive effects of the *Toxoplasma* infection on the career outcome can also be just as transient. Here, I decided to test five Houdek's predictions concerning the better career output of infected subjects.

In one of our ongoing studies, we had already collected questionaire data from nearly fourty thousand Czech volunteers, primarily members of the Facebook group 'Guinea pigs' (Kankova, Flegr, & Calda, 2015). Within our electronic questionnaire focusing on the sexual behavior of the Czech population, we included questions asking how many subordinates the responder presently had at his/her work, and how satisfied he/she was with his/her current economic situation. The questionnaire also contained the 12 items of the assertiveness scale of the International Personality Item Pool (Goldberg, 1999).

The assertiveness questions, the questions concerning the number of subordinates (proxy of the leadership skills) and the question on the satisfaction with current economic situation, were answered by 5075, 3689 and 4823 subjects, respectively, who knew their toxoplasmosis status. The population consisted of 45.9% men and 54.1% women and the prevalence of toxoplasmosis was 7.6% in men and 16.4% in women. The effect of toxoplasmosis was analyzed by multivariate ANCOVA with three binary factors: toxoplasmosis, sex, youth and their interactions, and two confounding variables: achieved education level, and size of the place where they spent their childhood. The output variable "number

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TABLE 1

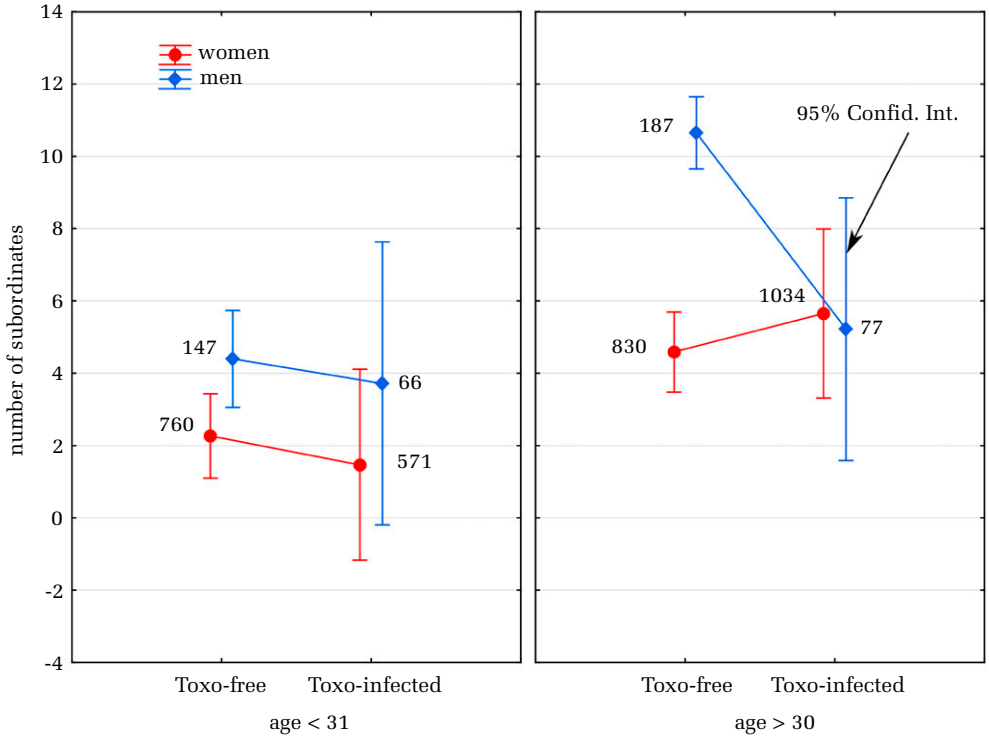
	subordinates		assertiveness		economic situation	
	p	Partial eta^2	p	Partial eta^2	p	Partial eta^2
Intercept	0.000	0.040	0.000	0.455	0.000	0.223
size of place of living	0.093	0.001	0.013	0.001	0.271	0.000
education	0.000	0.011	0.000	0.008	0.000	0.038
toxoplasmosis	0.002	0.003	0.322	0.000	0.010	0.001
sex	0.000	0.008	0.000	0.019	0.000	0.004
youth	0.000	0.023	0.000	0.012	0.002	0.002
toxoplasmosis-sex	0.006	0.002	0.932	0.000	0.299	0.000
toxoplasmosis-youth	0.656	0.000	0.852	0.000	0.329	0.000
sex-youth	0.216	0.000	0.082	0.001	0.555	0.000
toxoplasmosis-sex-youth	0.619	0.000	0.981	0.000	0.214	0.000

Results of three multivariate ANCOVAs for the output variables the number of subordinates, assertiveness, and satisfaction with personal economic situation. The values lower than 0.00005 were coded as 0.000.

of subordinates" had no-normal distribution; therefore this variable was log-transformed before the analysis. However, the results were qualitatively the same when a nonparametric test, namely the partial Kendall correlation (controlled for age) was used for the analysis.

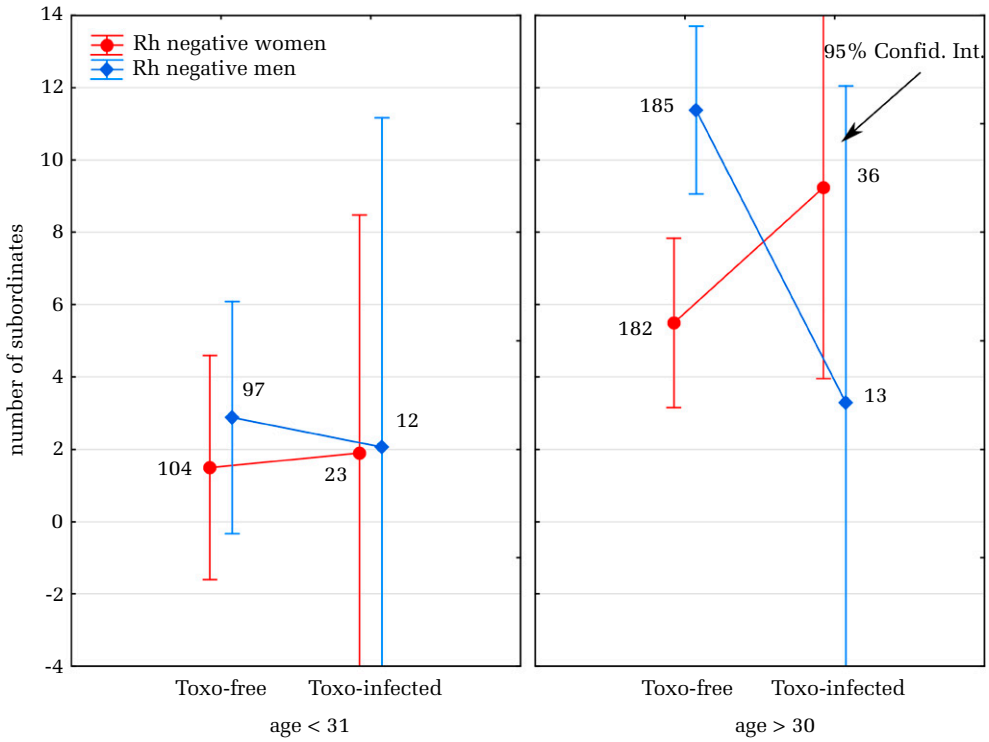
The results of the ANCOVA analysis (Table 1) showed significant effects of toxoplasmosis and

FIGURE 1
Effect of toxoplasmosis and gender on number of subordinates



The numbers denote amount of responders in particular groups. The means reflect, but not correspond to, number of subordinates as for 0-100 one point on the scale corresponded to one subordinate while for 101-140 one point on the scale corresponded to 10 subordinates. The code 141 meant 500 and more subordinates (this code was used by 14 participants).

FIGURE 2
Effect of toxoplasmosis and gender on number of subordinates in Rh negative responders



For the legend see the Fig. 1.

toxoplasmosis-sex interaction. The Figs. 1 and 2 illustrate the effects of toxoplasmosis on number of subordinates and the satisfaction of participants with their economic situation and also the absence of any effect of triple interaction toxoplasmosis-sex-youth.

The results suggest that the latent *Toxoplasma* infection could have impacts on career outcome. However, the observed effects contrasted with those based on prediction of Houdek (2017).

Prediction 1: ***Infected subjects should have higher number of subordinates due to increased concentration of testosterone in men and increased extroversion/warmth in women.*** *In fact, the infected men had a lower number of subordinates. No effect of the infection on the number of subordinates was observed in women.*

Prediction 2: ***Toxoplasmosis may be a partial culprit in the inequality in leading positions in men and women due to their specific (positive) effect on the level of testosterone in men.*** *In fact, toxoplasmosis had a very opposite effect on the inequality in leading positions. Among the Toxoplasma-free participants, the men reported much higher numbers of subordinates than the women. In contrast, the number of reported subordinates was approximately same in the Toxoplasma-infected men and women after the age 30 (actually it was a little bit lower in men).*

Prediction 3: ***The career dynamics of the Toxoplasma-infected subjects would look like "shine brightly and burn out", as they would more frequently fail at their task due to their lower consciousness.*** *This prediction can be right, however, we found no formal evidence for it as the effects of triple interaction toxoplasmosis-sex-youth and binary interaction toxoplasmosis-youth were not significant. However, the negative effects of toxoplasmosis on the number of subordinates and on the self-reported economic situation seem to be much stronger after the age 30.*

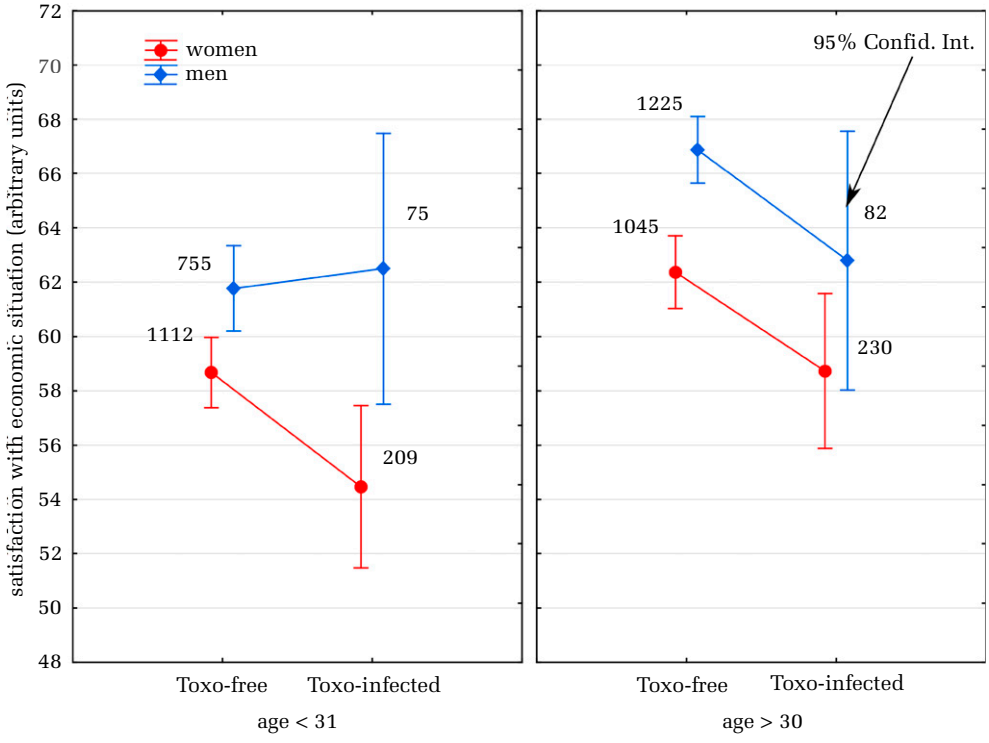
Prediction 4: ***The effects of toxoplasmosis on career outputs should be stronger in***

subjects with the blood group Rh minus because the Rh positive subjects, namely Rh positive heterozygotes, are protected against most of the negative effects of toxoplasmosis. *This prediction is most probably right, despite the fact that (due to low number of Rh negative, Toxoplasma-infected men) the corresponding effects were not significant. The comparison of the figures 1 with 2 and 3 with 4 suggests that the effect of toxoplasmosis on the number of subordinates and the satisfaction with economic situation is stronger in Rh negative subjects than that observed in the whole population.*

Prediction 5: ***Toxoplasmosis could affect the quality of relationships between men and women in workplaces or the prevalence of sexual harassment in firms as the infected men have higher testosterone levels and the infected women tend to exhibit more warmth****. In fact, both Toxoplasma-infected men and women reported to have problems with too low sexual desire (men: p = 0.028, Tau = 0.04; women: p = 0.041, Tau = 0.03), lower frequency of sexual intercourses within past 365 days (men: p < 0.00001, Tau = -0.08; women: p = 0.049, Tau = -0.03), and men also reported lower numbers of sexual partners within past 365 days (p = 0.005, Tau = -0.05). More details on specific effects of toxoplasmosis on sexual life of men and women can be found in our recent publication (Flegr & Kuba, 2016).*

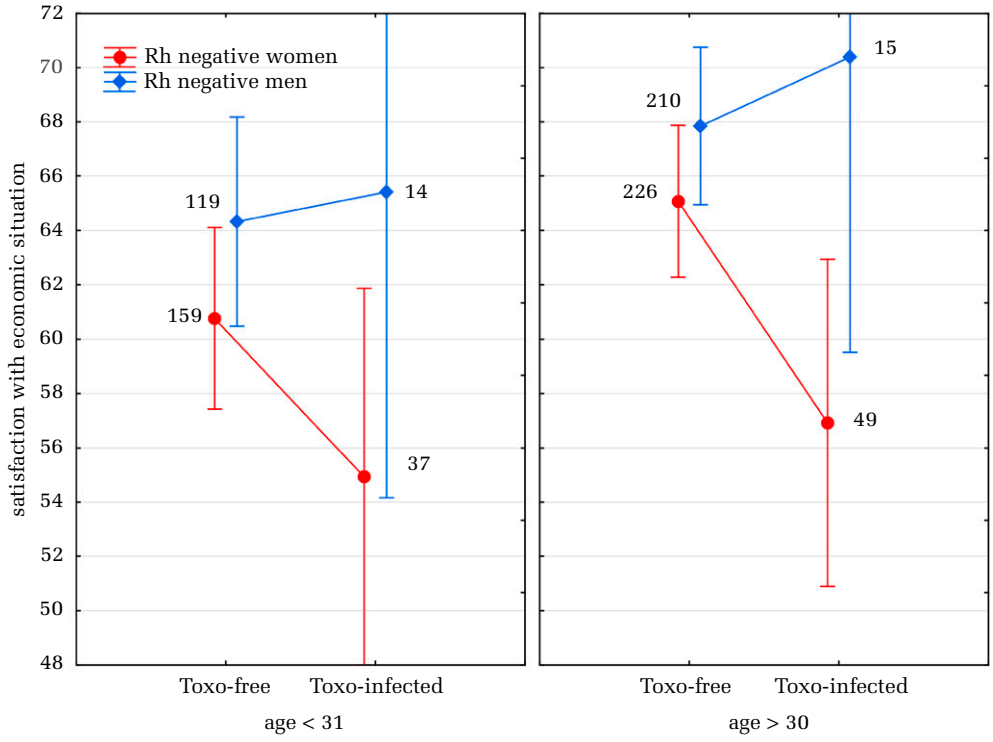
The most probable explanation for the contradiction between the theoretical predictions and the empirical data is that other effects of toxoplasmosis, possibly its effects on the health of infected subjects, cancel out the behavioral effects of increased concentration of testosterone and higher extroversion. It has been published that toxoplasmosis increases incidence and morbidity of many disorders, including some cardiovascular diseases, mental health disorders and certain types of cancer, for review see (Flegr, Prandota, Sovickova, & Israili, 2014). In the

FIGURE 3
Effect of toxoplasmosis and gender on self-reported satisfaction with personal economic situation



The numbers denote amount of responders in particular groups. The responders used 0-100 scale to rate the satisfaction with their personal economic situations.

FIGURE 4
Effect of toxoplasmosis and gender on self-reported satisfaction with personal economic situation in Rh negative responders



For the legend see the Fig. 3.

present study, several health-related variables were monitored. It was observed that infected men reported to have visited a higher number medical specialists within the past two years (p = 0.032, Tau = 0.04) while infected women more frequently reported to have worse mental health (p < 0.0001, Tau = 0.07), to have more psychiatric disorders diagnosed by medical specialists, (p = 0.002, Tau = 0.06), and consumed more types of drugs prescribed by medical doctors (p = 0.006, Tau = 0.05) (Flegr & Escudero, 2016). It must be admitted, however, that our data also showed very strong effects of the infection with the bacterium *Borrelia burgdorferi* (the cause of Lime borreliosis) on the physical health of our responders (much stronger than the effects of toxoplasmosis). At the same time, this infection had no effects on the number of subordinates or on the satisfaction with personal economic situation. Possibly, some more specific effects of latent toxoplasmosis (its effects on mental health?) or on motivation (Flegr, Novotná, Lindová, & Havlíček, 2008) are responsible for the observed impacts of the *Toxoplasma* infection on the career outputs. There are some indirect indices for lower ambitiousness of the infected subjects. The present electronic questionnaire contained also a short projective test. The subjects were asked if they would be born as an animal in their next life, which of ten different animals they would prefer to be. In the *Toxoplasma*-free men, the most popular animal was the lion and in women the dog. In the *Toxoplasma*-infected men the most popular animal was dog and in the infected women the cat. It is indicative that the largest negative difference between popularity in the *Toxoplasma*-infected and *Toxoplasma*-free men, i.e., the largest *Toxoplasma*-associated decrease in popularity, suffered the lion (p < 0.0001, Tau = -0.07), the dog (n.s.) and the largest increase in popularity underwent the cat (p < 0.0001, Tau = 0.09) and the squirrel (p < 0.0001, Tau = 0.09). In the women, popularity of all animals was higher in the *Toxoplasma*-infected raters. However, the smallest increase was in the dog (n.s.) and the parrot (n.s.), and the lion (n.s.) while the largest was in the

cat ($p < 0.0001$, Tau = 0.09) and the mice ($p < 0.0001$, Tau = 0.09). These results suggest that infected men and women have lower ambitiousness than their *Toxoplasma*-free peers (or they would all enjoy turning into cats, which the cats parasite *Toxoplasma* must greatly enjoy).

DISCUSSION

There are several explanations for the difference between present empirical data and Houdek's theoretical predictions. Most likely, the toxoplasmosis-associated increase of testosterone is just transient, and after some time it returns to its original (or an even lower) level, possibly due to cumulative negative effects of latent toxoplasmosis on human health (Flegr & Escudero, 2016). A very similar phenomenon has been already described (Kaňková et al., 2007). Women infected with *Toxoplasma* for less than two years give birth to 2.5 more sons than daughters, while the women infected for a longer time give birth to significantly more daughters than sons. The long term negative effect of toxoplasmosis on offspring sex ratio is more important than the transient positive effect of toxoplasmosis on the offspring sex ratio, as the secondary sex ratio (fraction of newborn males) correlates negatively with prevalence of toxoplasmosis in particular countries (Dama, Novakova, & Flegr, 2016). Despite the fact that our data brought no formal proof for this, Houdek could be right when saying: "*Toxoplasma*-positive people can achieve high positions, but their performance may decline due to a decrease in conscientiousness, increased neuroticism, and possible health risks." Houdek (2017) p. 71.

Limitations of present study

The participants provided information, about their *T. gondii* infection status themselves. Some of them probably provided incorrect information and some of them may have provided obsolete information because they acquired the infection only after their test for anti-*T. gondii* antibodies had been done. However, an independent analysis showed excellent (99·5%) agreement between the toxoplasmosis status reported by 3,827 subjects during registration to Guinea Pigs community and the toxoplasmosis status obtained in serological tests performed in our laboratory (Flegr, 2017). The same study also reported very good (99·2%) agreement in 393 responders who signed their questionnaire in a previous epidemiological study and also reported their toxoplasmosis status during registration (Flegr, 2017). The subjects also self-reported how many subordinates they have. It is probable that this information can be imprecise or even biased. The personality profiles of *Toxoplasma*-infected and *Toxoplasma*-free subjects differ (Flegr, 2010). The infected subjects have, e.g., lower conscientiousness, and therefore it is possible that they do not know how many subordinates they, in fact, have. Because of this, the infected subjects could report to have less subordinates, despite having the same (or a higher) a number of subordinates than the *Toxoplasma*-free subjects. Therefore, it would be important to confirm the results of the present study and the original study performed on the university professors using independent empirical case control studies, i.e., by comparing the seroprevalences of toxoplasmosis in subjects in various working positions.

CONCLUSIONS

The present data confirmed that *Toxoplasma* infection probably had certain effects on career outcome. However, in most subjects, various effects of toxoplasmosis on human physiology and behavior or even the nonspecific effects of impaired health status have probably had stronger impacts than the more specific, but weaker, effects of the changed levels of hormones and neurotransmitters. These conclusions are based on the analysis of data of just one very large new and one small already published study and both these studies were originally designed to solve unrelated questions. Therefore, the results and conclusions must be considered only preliminary until the results of other independent and specifically designed studies will be available.

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