Original Article

The Relation of *Toxoplasma* Infection and Sexual Attraction to Fear, Danger, Pain, and Submissiveness

Evolutionary Psychology
July-September 2016: 1–10

DOI: 10.1177/1474704916659746
evp.sagepub.com
SAGE

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Abstract

Behavioral patterns, including sexual behavioral patterns, are usually understood as biological adaptations increasing the fitness of their carriers. Many parasites, so-called manipulators, are known to induce changes in the behavior of their hosts to increase their own fitness. Such changes are also induced by a parasite of cats, *Toxoplasma gondii*. The most remarkable change is the fatal attraction phenomenon, the switch of infected mice's and rat's native fear of the smell of cats toward an attraction to this smell. The stimuli that activate fear-related circuits in healthy rodents start to also activate sex-related circuits in the infected animals. An analogy of the fatal attraction phenomenon has also been observed in infected humans. Therefore, we tried to test a hypothesis that sexual arousal by fear-, violence-, and danger-related stimuli occurs more frequently in *Toxoplasma*-infected subjects. A cross-sectional cohort study performed on 36,564 subjects (5,087 *Toxoplasma* free and 741 *Toxoplasma* infected) showed that infected and noninfected subjects differ in their sexual behavior, fantasies, and preferences when age, health, and the size of the place where they spent childhood were controlled ($F(24, 3719) = 2.800$, $p < .0001$). In agreement with our a priori hypothesis, infected subjects are more often aroused by their own fear, danger, and sexual submission although they practice more conventional sexual activities than *Toxoplasma*-free subjects. We suggest that the later changes can be related to a decrease in the personality trait of novelty seeking in infected subjects, which is potentially a side effect of increased concentration of dopamine in their brain.

Keywords

Toxoplasma gondii, sexual behavior, sadism, sexual domination, sexuality

Date received: September 22, 2015; Accepted: June 24, 2016

Biologists are usually inclined to explain sexual preferences and behavior as biological adaptations covering individual reproductive success (Barbaro, Pham, & Shackelford, 2015; Barthes, Crochet, & Raymond, 2015; Hellstrand & Chrysochoou, 2015; Russell, DelPriore, Butterfield, & Hill, 2013). Such an interpretation concerns not only the "normal" sexual behavior and preferences expressed by a majority of people but also less frequent behavioral patterns, such as homosexuality, sadism, masochism, fetishism, and so on. Alternative sexual patterns are present in all populations in relatively high and constant frequencies, suggesting that these are sustained there by some form of selection, for example, frequency dependent selection rather than represent a part of sexual pathology. It has been, for example, suggested that male homosexuality can increase either the direct fitness of its carrier (Dewar, 2003; Macintyre & Estep, 1993) or it can increase his inclusive fitness by channeling resources toward his female relatives (Kirby, 2003; Rahman & Hull, 2005). Similarly, sexual dominance and sexual submissiveness have been suggested to increase the biological fitness of individuals by increasing the likelihood of women expressing sexual submissiveness, for example, masochism, to acquire "good genes" or "good resources" from dominant men (Jozifkova, Bartos, & Flegr,

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2012). It has also been suggested that sexual dominance and submissiveness could increase in-pair cohesion and cooperation which could consequently result in an increased number of offspring in hierarchically disparate couples even within a modern community (Jozifkova, Konvicka, & Flegr, 2014).

An alternative evolutionary explanation of less frequent sexual behavior traits and sexual preferences is suggested by the general conception of extended phenotype (Dawkins, 1983) and its special application, the parasite manipulation theory (Moore, 2002). Certain categories of phenotypic traits of an organism could be the products of genes sitting within a body of other biological species and increasing their own between-generation transmission potential often at the expense of the fitness of carriers of these traits. Many parasites can change the morphology or behavior of their host in such a way that increases the efficiency of their transmission from an infected to noninfected host. Such manipulative activity was observed in many parasites transmitted from intermediate hosts to definitive hosts by predation. In human parasites, manipulative activity, both the induction of morphological and behavioral changes, was observed in the protozoan parasite *Toxoplasma gondii* (Flegr & Hrdý, 1994; Webster, 1994). This parasite can infect any warm-blooded animal, including about one third of humans worldwide (Pappas, Roussos, & Falagas, 2009; Tenter, Heckeroth, & Weiss, 2000). *Toxoplasma* can reproduce sexually in an intestine of its definitive host, a cat. It has been known for a long time that the parasite may live dormant for years in tissue cysts in immunoprivileged organs, inducing many behavioral changes in its intermediate host. For example, it prolongs the reaction times of its host, increases its vigility, and alters the tendency to seek new stimuli (Flegr et al., 2003; Hodková, Kodym, & Flegr, 2007; Hrdá, Votýpka, Kodym, & Flegr, 2000). The most remarkable toxoplasmosis-associated behavioral change is the so-called fatal attraction phenomenon—the switch from the mice's and rats' native fear of the smell of cats toward an attraction to this smell (Berdoy, Webster, & Macdonald, 2000). The existence of this phenomenon has been observed in mice and rats in about 20 studies performed in several laboratories worldwide and its analogy, higher ratings of attractiveness of smell of highly diluted cat (but not other species) urine was observed even in humans (Flegr, Lenochová, Hodný, & Vondrová, 2011). The neurological mechanism of this change in rats was revealed recently. It was shown that in the infected rats expressing fatal attraction, *Toxoplasma* is able to reprogram the brain's genetic machinery by specific demethylation of certain regulatory elements of genes (Dass & Vyas, 2014). The cat odor activates fear-associated medial amygdala circuits in normal rodents. In the *Toxoplasma*-infected rodents, the same odor also activates the amygdala circuits responsible for sexual behavior. It is possible that *Toxoplasma* could increase its chances for alimentary transmission from infected rodents to cat intestine by making any perceived danger (not just the odor of cats) ''smell sexy'' to the infected host. Currently, between 10% and 80% of people are infected in most countries (Pappas et al., 2009; Tenter et al., 2000). However, less than 100 years ago, most of the population was probably infected in all countries where feline hosts of *Toxoplasma* lived, that is, nearly everywhere. It is therefore possible that sexual preferences and behaviors are at least partly influenced by the *Toxoplasma* infection. It is even possible that the frequent association of sexual arousal with violence, danger, fear, and exchange of power could be a product of manipulation activity of *Toxoplasma*, which was adaptive in its natural hosts—the rodents (Flegr & Markos, 2014).

In the present study, we tested a hypothesis that *Toxoplasma*-infected and *Toxoplasma*-free subjects differ in their sexual behavior, desires, and preferences. Specifically, we tested our animal studies-based hypothesis that the infected subjects were more often sexually aroused by their own fear, danger, and sexual submission. For this purpose, we ran a large-scale cross-sectional questionnaire study on the Internet population with a precise number of 36,564 Czech and Slovak people who completed the survey.

Material and Method

Subjects

The Internet questionnaire was distributed as a Qualtrics survey. The subjects were invited to participate in the study using a Facebook-based snowball method (Kankova, Flegr, & Calda, 2015) by posting an invitation to participate in a ''study testing certain evolutionary psychological and parasitological hypotheses, containing many questions related to sexual life'' on the wall of the Facebook page ''guinea pigs'' (''Pokusní králíci'' in Czech) for Czech and Slovak nationals willing to take part in diverse evolutionary psychological experiments (www.facebook.com/pokusnikralici). The participants were informed about the aims of the study on the first page of the electronic questionnaire. They were also provided with the following information: ''The questionnaire is anonymous and obtained data will be used exclusively for scientific purposes. Your cooperation in the project is voluntary and you can terminate it at any time by closing this web page. You can also skip any uncomfortable questions; however, the most valuable are the complete data. Only subjects above 15 years old are allowed to take the questionnaire. If you agree to participate in the research and are above 15, press the 'Next' button.'' Some pages of the questionnaire contained the Facebook share button. These buttons were pressed by 1,163 participants, which resulted in obtaining data from 36,564 responders in total between January 22, 2015, and February 11, 2016. The project, including the method of obtaining an electronic consent with a participation in the study, was approved by the institutional review board of the Faculty of Science, Charles University (Komise pro práci s lidmi a lidským materiálem Přírodovědecké Fakulty Univerzity Karlovy), No. 2015/01.

Questionnaires

The electronic survey = Sexual Preferences and Behaviors Inventory 2015 (SPBI-2015) consisted of five already published

questionnaires studying various facets of human sexuality, such as the Hurlbert Index of Sexual Narcissism (Hurlbert, Apt, Gasar, & Wilson, 1994), the Revised Sociosexual Orientation Inventory (SOI–R) (Penke & Asendorpf, 2008), the Three-Domain Disgust Scale (Tybur, Lieberman, & Griskevicius, 2009), the International Personality Item Pool (IPIP)–Dominance Scale (Goldberg, 1999; Goldberg et al., 2006), and the Attraction to Sexual Aggression Scale (Malamuth, 1989) modified and supplemented with questions to cover a broader spectrum of sexual preferences and sexual behaviors. The survey also contained a questionnaire collecting various socioeconomic, demographic, health-related, epidemiologic and psychological data, and three projective psychological tests. Altogether, the survey consisted of 701 questions (a few more in female version) and the mean time necessary to complete it was about 89 min (the mode was 72 min). In the present study, we used only the information about gender, age, the size of the population of the town where the responders spent most of their childhood rated on 6-point scale, sexuality-related questions, and three health-related questions (physical and psychological conditions rated on 6-point scales and number of specialized medical doctors the subject had to regularly attend [not for prevention] at least once in the past 5 years). The subject also had to answer a question "Are you infected with *Toxoplasma*, the cat parasite that is dangerous especially to pregnant women?" by ticking one of the three suggested answers: "I do not know or am not sure, I was not laboratory tested," "No (I was tested by a medical doctor and the blood test gave a negative result," and "Yes (I was tested by a medical doctor and the blood test gave a positive result." Implicitly, the first answer ("I do not know ...") was ticked.

At the end of the questionnaire, the participants could provide their unique "guinea pig code." Because of the rather sensitive sex- and health-related contents of this questionnaire, it was "signed" only by 8% of the responders. However, other questionnaires distributed in this community were signed by most of responders (Flegr & Hodny, 2016). These results showed that most of participants who were aware of their toxoplasmosis status (and nearly all male responders) had been tested for toxoplasmosis in our lab. We always used complement fixation test, IgG enzyme-linked immunosorbent assay (ELISA), and IgM ELISA tests to reveal the *Toxoplasma* infection and to discriminate between acute and latent form of the infection (Flegr, Kodym, & Tolarová, 2000).

Statistical Method

Before statistical analysis, we filtered out less than 1% of our data because it appeared suspicious (too high or too short body height, too low or too high body mass or age, too short duration of the test, etc.).

IBM SPSS Statistics 21.0 was used for all statistical tests including factor analysis (principal axis factoring [PAF], mean substitution of missing data, and direct oblimin normalized rotation). We computed optimal number of independent factors using parallel analysis (O'Connor, 2000).

Associations between ordinal and binary data were analyzed by partial Kendall's correlation test (Kaňková, Kodym, & Flegr, 2011; Siegel & Castellan, 1988). This test measures the strength and significance of association between binary, ordinal, and continuous data regardless of their distributions. The partial Kendall's τ reflects the probability that the value of a particular dependent variable for the Subject A is higher than for Subject B when the value of an independent variable for Subject A is higher than for the Subject B. This technique enabled us to control for one confounding variable, for example, the age of a responder. The Excel sheet for computing partial Kendall's τ and the significance between Variables A and B after the Variable C is controlled based on Kendall τ's AB, AC, and BC. It is available at http://web.natur.cuni.cz/flegr/programy.php. Toxoplasmosis is known to have different, often opposite impacts on the behavior and personality men and women. Therefore, we performed all analyses for all responders and also separately for the male and female responders.

Results

The final data set of 36,564 responders contained records of 2,470 *Toxoplasma*-free men (age 37.86, $SD = 13.99$), 212 *Toxoplasma*-infected men (age 36.15, $SD = 13.97$), 2,617 *Toxoplasma*-free women (age 33.73, $SD = 11.91$), and 529 *Toxoplasma*-infected women (age 34.83, $SD = 11.28$). Infected women were older than noninfected women ($t(3146) = -2.034$, $p = .042$); the difference in age between infected and noninfected men was not significant ($t(2682) = 1.711$, $p = .088$). The prevalence of toxoplasmosis in women (16.8%) was higher than in men (7.9%), $\chi^2 = 103.575$, $p < .00001$.

The sexual behavior, desires, and preference of responders were characterized by 350 variables, including their responses to abovementioned standard questionnaires (Sexual Narcissism, Sexual Attitude Scale SOI-R, Disgust Scale, Dominance Scale, and modified Attraction to Sexual Aggression Scale) and questions of our SPBI-2015 (see Online Supplement 1) and the questionnaire concerning sexual preferences and types of pornography watched.

We computed the optimal number of 24 independent factors using parallel analysis. The actual eigenvalues from PAF and the random order eigenvalues from parallel analysis are illustrated in Figure 1.

Therefore, the factor analysis reduced variables to 24 independent factors with eigenvalues higher than 2.361 that together explained 53.034% of the between-subject's variance of sexual behavior and preferences. The nature of most of these factors was able to be identified on the basis of variables that positively or negatively loaded particular factors—factor names as well as example items defining the factors and the eigenvalue for each factor are represented in Table 1 (for full detail, see Online Supplement 2).

A multivariate analysis of variance with all 24 factors as dependent variables showed a significant effect of toxoplasmosis for all subjects ($F(24, 5828) = 3.506$, $p < .0001$),

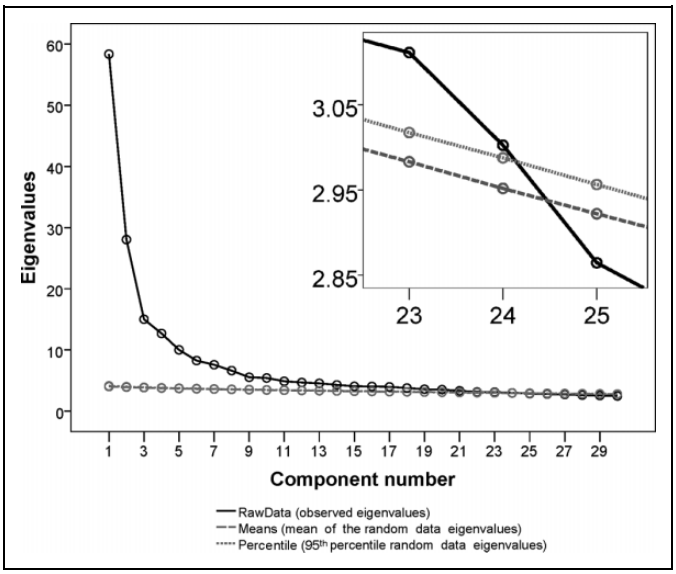

Figure 1. Eigenvalues for parallel analysis and principal axis factoring.

men ($F(24, 2682) = 2.358$, $p < .0001$), and women ($F(24, 3146) = 1.798$, $p = .001$). Regardless of the fact that age correlated with most of sexual life–related factors, the multivariate analyses of covariance with toxoplasmosis status and the age of subjects as independent variables gave nearly identical results ($F(24, 5828) = 3.484$, $p < .0001$), men ($F(24, 2682) = 2.290$, $p < .0001$), and women ($F(24, 3146) = 1.782$, $p = .011$). Very similar results were also obtained when a larger set of potential confounding variables, namely, age, population size of the place of residence, self-rated physical conditions, psychical conditions, and the number of medical specialists visited more than once during the past 5 years were controlled: all ($F(24, 3719) = 2.800$, $p < .0001$), men ($F(24, 1542) = 1.899$, $p = .005$), and women ($F(24, 2177) = 1.732$, $p = .015$). Here, the number of subjects was lower, and therefore p values were higher as not all subjects responded to all questions.

Most sexual life–related factors had nonnormal distribution. To avoid performing a different type of transformation for each of 24 different factors, we used the nonparametric Kendall method for searching for association between toxoplasmosis and particular factors. We used nonparametric partial Kendall correlation test that enabled us to control for one confounding variable, here the age of responders. The results presented in Table 2 show that 18 of the 24 sex life–related factors, included the factor F3 (violence-associated arousal), expressed significant association with *Toxoplasma* infection for all subject, 11 for women, and 12 for men. Most of the observed associations (32) were significant after backward sequential correction for multiple tests (Table 2) and many of them (21), including that for sadism, remained significant even after the most conservative simple Bonferroni's correction for multiple tests. Moreover, the number of observed significant associations was 41, that is, 10^{10} times higher than was the theoretical number of false negative results for 72 tests.

Results of partial Kendall's τ correlations between 24 sex-related factors obtained by factor analysis and *Toxoplasma* infection. The effect of age of subject was controlled. The absence and presence of *Toxoplasma* infection was coded with 1 and 2, respectively. Therefore, positive τs corresponded to positive association between particular factor and toxoplasmosis. Significant results are marked bold and .000 denote $p < .0005$. The asterisks denote that the associations are significant after backward sequential correction for multiple tests.

Discussion

Latent toxoplasmosis had specific effects on human sexual life–related traits. The infected subjects expressed a lower tendency toward sexual dominance, tattoo and piercing, watching pornography, group sex, and they are less often engaged in activities that include Bondage, Discipline and Sado-Masochism (BDSM). However, they expressed higher attraction to bondage, violence, zoophilia, fetishism, and, in men, also to masochism, and raping and being raped. Generally, infected subjects expressed higher attraction to nonconventional sexual practices, especially the BDSM-related practices, but they also reported to perform such activities less often than the *Toxoplasma*-free subjects. These observations agreed with our animal studies-based hypothesis of coactivation of danger- and sex-related hypothalamic circuits in *Toxoplasma*-infected subjects (Dass & Vyas, 2014; Flegr & Markos, 2014).

The relation between sex and danger, fear, power exchange, and pain is rather close in human populations. Kinsey's data showed that about 12% of women and 22% of men reported having an erotic response to a sadomasochistic story and 55% of women and 50% of men reported having responded erotically to being bitten. Janus and Janus (1993) showed that about 14% of male and 11% of female responders in the United States had personal experience with sadomasochistic (SM) sexual practices and about 8–10% of responders had some SM "toys" at their homes. An Australian study showed that 2% men and 1.4% women had during last 6 months participated in SM activities (Richters, Grulich, de Visser, Smith, & Rissel, 2003). Preferences for BDSM activities in the Czech Republic were studied by an Internet trap method (Jozífková & Flegr, 2006). The subjects who clicked the banner displayed in the web interface of e-mail boxes of main Czech free e-mail provider were offered to choose graphic gates labeled with icons of homosexual or heterosexual partner of different hierarchical position (submissive, equal, and dominant). About 13.5% of men and 20.5% of women had chosen dominant partners and 36.6% of men and 19.8% women had chosen submissive partners. In the current questionnaire study, the men and woman were asked to rate how much they were sexually aroused by their own or somebody else's powerlessness using 6-point scale anchored with 0 (*not at all*) 5 (*very strongly*). Being aroused by one's own powerlessness (ratings 3–5) was reported by 20.04% of men and 18.45% women, while being aroused by somebody else's powerlessness was reported by 33.55% of men and 11.34% of women. *Toxoplasma* probably only slightly increases the tendencies of infected subjects to be sexually aroused by BDSM stimuli and especially by sexual

Table 1. The Listing of Factor Names as Well as Example Items Defining the Factors and Eigenvalues for Each Factor.

Factor Number, Name, and Example of Items Defining the Factor	Eigenvalues
F01 sadism/sexual dominance: Sexually aroused when someone else is feeling fear, danger, pain, powerlessness, or humiliation. Not sexually aroused when feeling his own fear, danger, pain, powerlessness, or humiliation.	55.08
F02 homosexuality (french kiss and oral sex): Sexually aroused by people of the same sex and performing homosexual activities (e.g., french kissing, oral sex, and anal sex). Not sexually aroused by people of the opposite sex and doing homosexual activities (e.g., french kissing, oral sex, and anal sex).	21.87
F03 violence (aroused by): Sexually aroused by feeling fear, danger, pain, powerless, or humiliated in general (own and someone else's)	14.07
F04 french kiss (attractiveness): The respondent stated higher affinity toward heterosexual french kissing (thinking of trying, attractiveness in general, quantity of engaging, and attractiveness in virtual reality)	11.81
F05 piercing and tattoo (having): The respondent stated more body piercings and tatoos (on face and on intimate body parts).	9.59
F06 tattoo and piercing (intimate attractiveness): The respondent stated higher attractiveness to body piercing and tatoos (on face and on intimate body parts).	8.23
F07 sexual submissiveness/masochism: Sexually aroused when feeling his own fear, danger, pain, powerlessness, or humiliation.	7.12
F08 SOI-R (promiscuity and no attachment): The respondent stated higher numbers of sexual partners, doesn't have problem having sex with person without a long-term, serious relationship (SOI-R questionaire).	5.48
F09 raping: The respondent stated higher affinity to rape–role-play (thinking of trying, attractiveness in general, and attractiveness in virtual reality).	5.38
F10 bondage (attraction): The respondent stated higher affinity to bondage sex (thinking of trying, attractiveness in general, and attractiveness in virtual reality).	4.41
F11 SM porn watching: The respondent stated higher affinity to consumation of erotic materials (pictures, videos, etc.) covering especially sadomasochistic sexual themes (torture, tying, spanking, whipping, etc.).	4.11
F12 pathogens-related disgust: The respondent stated higher pathogens-related disgust (dog's excrement, red sores, sweaty hands, mildew-in-fridge, smelly person, etc.; Three-Domain Disgust Scale).	3.98
F13 attractiveness in virtual reality: The respondent stated higher affinity toward several sexual activities but only in virtual reality (heterosexual french kissing, group sex, oral sex, anal sex, bondage-discipline sex, and sex with sadomasochistic themes).	3.50
F14 non-BDSM porn watching: The respondent stated higher affinity toward consumation of erotic materials (pictures, videos, etc.) covering non-BDSM themes (e.g., general nudity, genitals, group sex, homosexual sex, oral sex, and gentle porn).	3.41
F15 missing some sex activity: The respondent stated an affinity toward some sexual activity not listed in our questionaire—they could add it and rate the frequency of thinking of trying, attractiveness in general, quantity of engaging, and attractiveness in virtual reality.	3.22
F16 group sex, more same-sex participants (attractiveness): The respondent stated higher affinity toward group sex activities with one opposite sex and several same-sex partners (thinking of trying, attractiveness in general, and attractiveness in virtual reality).	3.09
F17 sadomasochism (doing): The respondent stated higher quantity of engagement in several sadomasochistic activities (e.g., bondage-discipline sex, sex covering powerlessness, pain, threat, humilliation, and role-plays).	3.03
F18 homosexual sex (doing): The respondent stated higher quantity of engagement in several homosexual activities (e.g., french kissing, homosexual group sex, oral sex, and anal sex).	2.89
F19 morality-related disgust: The respondent stated higher morality-related disgust (theft of candy bar, robbing a neighbor, student cheating, faking signature, and jumping the queue stated as disgusting; Three-Domain Disgust Scale).	2.83
F20 sexual narcissism (no emotion): The respondent obtained a higher score in the questions of the "Hurlbert Index of Sexual Narcissism" covering emotional dimension (e.g., he or she stated that their relationship can keep them from engaging in a lot of fulfilling sexual activities, not enough people have sex for fun anymore, that he or she has no sexual inhibitions, and that too much "relationship closeness" can interfere with sexual pleasure).	2.61
F21 tattoo—face + blood (attractiveness): The respondent stated higher attractiveness to face tatoos (active and also passive) and sexual arousal by manipulation with blood.	2.57
F22 zoophilia: The respondent stated higher affinity toward sex with animals (thinking of trying, attractiveness in general, quantity of engaging, and attractiveness in virtual reality).	2.56
F23 anal sex and nude photos: The respondent stated higher affinity toward heterosexual anal sex and taking nude pictures (thinking of trying, attractiveness in general, quantity of engaging, and attractiveness in virtual reality).	2.41
F24 fetishism: The respondent stated higher affinity toward sexual arousal by activities covering fetish (objects such as velvet, latex, leather, underwear, banknotes, etc.) and also consumation of erotic materials (pictures, videos, etc.) covering especially fetishism.	2.36

submissiveness, one's own fear, and one's own pain in male subjects. It could hardly by fully responsible for humans' sexual arousal by BDSM stimuli, as the *Toxoplasma* infection explained only relatively small part of the between-subjects variability in BDSM-related traits. In its natural hosts, the rodents, even a small effect of infection on attractiveness of a smell of dangerous feline predators could result in the fatal attraction phenomenon, and by this, it can increase the chance of the parasite's transmission from intermediate to definitive host by predation.

Lower tendencies for performing nonconventional sexual practices in the infected subjects could be related to their

Table 2. Association Between Sex-Related Factors and *Toxoplasma* Infection.

Factor Number and Name	All, τ	*p*	*n*	Women, τ	*p*	*N*	Men, τ	*p*	*n*
F01: Sadism/sexual dominance	−.04	**.000***	5,828	−.01	.255	3,146	−.08	**.000***	2,682
F02: Homosexuality (french kiss and oral sex)	.01	.103	5,828	.03	**.005***	3,146	.02	.129	2,682
F03: Violence (aroused by)	.02	**.046**	5,828	.03	**.014***	3,146	.01	.427	2,682
F04: French kiss (attractiveness)	.00	.676	5,828	−.01	.611	3,146	−.01	.396	2,682
F05: Piercing and tattoo (having)	−.04	**.000***	5,828	−.02	.084	3,146	−.03	**.008***	2,682
F06: Tattoo and piercing (intimate attractiveness)	−.02	**.014***	5,828	−.01	.565	3,146	−.03	**.036**	2,682
F07: Sexual submissiveness/masochism	.00	.903	5,828	.00	.961	3,146	.04	**.004***	2,682
F08: SOI-R (promiscuity and no attachment)	−.04	**.000***	5,828	−.03	**.030**	3,146	−.01	.529	2,682
F09: Raping	.02	.050	5,828	.01	.389	3,146	.04	**.001***	2,682
F10: Bondage (attraction)	.03	**.001***	5,828	.02	.053	3,146	.06	**.000***	2,682
F11: SM porn watching	−.03	**.002***	5,828	−.02	.111	3,146	.01	.253	2,682
F12: Pathogens-related disgust	−.02	.079	5,828	−.03	**.005***	3,146	.01	.572	2,682
F13: Attractiveness in virtual reality	−.01	.093	5,828	−.03	**.032**	3,146	.01	.283	2,682
F14: Non-BDSM porn watching	−.04	**.000***	5,828	−.03	**.026**	3,146	.01	.263	2,682
F15: Missing some sex activity	.04	**.000***	5,828	.02	.102	3,146	.03	**.035**	2,682
F16: Group sex, more same-sex participants (attractiveness)	−.03	**.000***	5,828	−.01	.364	3,146	−.02	.244	2,682
F17: Sadomasochism (doing)	−.04	**.000***	5,828	−.05	**.000***	3,146	−.06	**.000***	2,682
F18: Homosexual sex (doing)	.04	**.000***	5,828	.02	**.037**	3,146	.05	**.000***	2,682
F19: Morality-related disgust	−.02	**.036**	5,828	.00	.820	3,146	−.01	.259	2,682
F20: Sexual narcissism (no emotion)	−.06	**.000***	5,828	−.04	**.001***	3,146	.06	**.000***	2,682
F21: Tattoo—face + blood (attractiveness)	−.03	**.000***	5,828	−.04	**.003***	3,146	−.04	**.001***	2,682
F22: Zoophilia	.02	**.026**	5,828	.03	**.012***	3,146	.00	.836	2,682
F23: Anal sex and nude photos	.03	**.000***	5,828	.01	.286	3,146	.06	**.000***	2,682
F24: Fetishism	.04	**.000***	5,828	.02	.057	3,146	.01	.522	2,682

Note. Significant results are marked bold and .000 denote $p < .0005$. The asterisks denote that the associations are significant after backward sequential correction for multiple tests.

impaired health status (Flegr, Prandota, Sovickova, & Israili, 2014). However, these negative associations were observed (especially in men) even when the health-related covariates were controlled. We suppose that a decrease of personality factor novelty seeking, which was observed in infected men and women in several studies (Flegr et al., 2003; Novotná et al., 2005; Skallová et al., 2005), could be responsible for the observed negative associations between toxoplasmosis and performing nonconventional sexual activities. This personality trait was measured, for example, by Cloninger's seven-factors Temperament and Character Inventory (TCI) questionnaire (Cloninger, Przybeck, Svrakic, & Wetzel, 1994) and is expected to negatively correlate with the concentration of dopamine in the ventral midbrain (Cloninger, Svrakic, & Przybeck, 1993). It was suggested that an observed decrease of novelty seeking is caused by increased concentration of this neurotransmitter in the brain of infected hosts, and this increased concentration could be responsible for higher incidence of schizophrenia of infected subjects (Flegr et al., 2003). It was originally supposed that the dopamine was produced by stimulated lymphocytes in the locally damaged brain tissue (Novotná et al., 2005). Later, it was observed that the *Toxoplasma* genome contains two genes for tyrosine hydroxylases, the enzymes catalyzing the key step in biochemical pathway of dopamine synthesis (Gaskell, Smith, Pinney, Westhead, & McConkey, 2009). Following studies showed that a large amount of this neurotransmitter is indeed synthetized in tissue cysts of *Toxoplasma* in the brain of infected rodents (Prandovszky et al., 2011). Novelty seeking (NS) has four subscales: Exploration Excitability, Impulsiveness, Extravagance, and Disorderliness. With the exception of the Exploration Excitability, the other three components of NS are lower in Toxoplasma-infected subjects. This means that infected people are on average more reflective, tend to require more detailed information when making an opinion, and are not easily distracted. They are also more reserved, slow, and controlled; they do not waste their energy and feelings. They tend to be organized, methodical, and prefer activities with strict rules and regulations. We suppose that these personality traits could result in observed differences in reported sexual preferences and activities.

It was observed that *Toxoplasma*-infected male subjects and male rats had higher level of testosterone (Flegr, Lindová, & Kodym, 2008; Vyas, 2013). Vyas and his group have shown that *Toxoplasma* upregulates the synthesis of this hormone by increasing the number of luteinizing hormone receptors on Leydig cells, that is, the receptors that regulate the synthesis of testosterone in testes (Lim, Kumar, Hari Dass, & Vyas, 2013). They suggested that this could be a part of the manipulation activity of the parasite aimed toward an increase sexual activity, which could enhance sexual transmission of *Toxoplasma* from infected males to noninfected females. Our current results provided no evidence of increased sexual activity of infected subjects. It is possible that the increase of testosterone observed in relatively young students and recently infected rats is just a transient effect of postacute toxoplasmosis, as many

other toxoplasmosis-associated changes are (Flegr et al., 2014; Hrdá et al., 2000; Kaňková, Kodym, et al., 2007; Kaňková, Šulc, et al., 2007), and disappears in later phases of infection or even turns into a decrease of concentration. Such a decrease was observed in infected male and female mice and in female students (Flegr, Lindová, Pivoňková, & Havlíček, 2008; Kaňková et al., 2011).

Homosexuality, that is, the sexual attractiveness of same sex but not opposite sex subjects—the second most important dimension obtained by the factor analysis—showed no association with toxoplasmosis. In contrast, the practicing homosexual sex, the factor F18, correlated positively with toxoplasmosis. This provides new support for the recent claims that toxoplasmosis could be most probably transmitted by unprotected sex (Flegr, Klapilová, & Kaňková, 2014). Men to men transmission by ejaculate could explain our nonpublished observation that high number of sexual partners was a highly important risk factor for acquiring toxoplasmosis not only for women but also for men.

We have no explanation for the robust results showing a positive association between *Toxoplasma* infection and zoophilia. Infected female subjects reported that they had sex with animals more often than *Toxoplasma*-free subjects. The most parsimonial, but still rather improbable, explanation of the observed pattern is that sex with some species of animal could be a source of *Toxoplasma* infection for humans. In our population, the female responders most often reported having sex with a dog. A dog is one of few animal species for which the experimental transmission by ejaculate has been demonstrated (Arantes et al., 2009).

Limitations of the Present Study

The major limitation of the present study is that it is based on self-reported information on subjects' sexual life and self-reported *Toxoplasma* infection status. It is highly probable that some subjects intentionally or unintentionally provided false information. Probably, only highly motivated people finished the 90-min questionnaire. At the end of the questionnaire, the responders were also asked to rate the percentage of truthfully answered sexual life–related questions. The mean answer was about 96%. We believe that most of responders really try to provide truthful answers. It is, of course, clear that some subjects that were tested negative for toxoplasmosis in the past could have acquired the *Toxoplasma* infection in meantime. Such misclassification could increase the risk of false negative not the risk of false positive results of statistical tests. Another limitation of the present study is a strong sieve effect that probably influenced the composition of the study population. People entered the study absolutely voluntarily and obtained no reward for their participation. It is highly probable that only certain kind of people (e.g., extreme altruists or people extremely interested in sex) voluntarily spent about 90 min answering the questions of the present electronic questionnaire. Therefore, the obtained results cannot be generalized to whole Czech population.

The Facebook community Guinea Pigs (Czech version of the website) primarily consists of subjects willing to regularly participate in various evolutionary psychology studies, and the present test was advertised as a part of the study focused on testing a nonspecified "evolutionary psychology and parasitology hypothesis." The whole 36,000 sets were used for the computation of sexuality-related factors. This Facebook community consists of people of various ages, education levels, occupations, and places of residence. However, most of the subjects (and nearly all the male subjects) who know their *Toxoplasma*-infection status are former students of biology who were tested for toxoplasmosis during systematic research of behavioral effects of latent toxoplasmosis which has been running at the Faculty of Science for the past 23 years. In last 2 years, the members of the Guinea Pigs community participated in several Internet studies that have mostly no relation to toxoplasmosis. The question on toxoplasmosis status was just one of several hundreds of questions to be responded by the participants of the study. The participants did not know that the present study tested the hypothesis about relation between toxoplasmosis and sexual life and especially the hypothesis concerning sexual dominance and toxoplasmosis. However, the personality profile of infected and noninfected subjects is known to differ (Flegr, 2013) and therefore observed differences in sexual life–related factors could be just side effects of these general personality differences. In the future, instrumental sexological methods should be used to confirm the existence of differences in sexual preferences of *Toxoplasma*-infected and *Toxoplasma*-free subjects.

Many of the observed effects are highly significant even after the most conservative Bonferroni's correction for multiple tests partly because of the large number of participants. However, their effect sizes are relatively low but comparable with those of other already published behavioral effects of latent toxoplasmosis. It has been discussed earlier (Flegr, 2013) that due to the large variability of human populations in particular behavioral traits and also in the size and direction of behavioral responses to particular environmental and genetic factors, toxoplasmosis usually explains only between 1% and 5% of the variability of behavioral traits. For example, the recently observed effect of toxoplasmosis on performance of students in acoustic reaction time test explained between 2% and 3% of the variability in the subjects' performance (Priplatova, Sebankova, & Flegr, 2014). Probably the strongest effect of latent toxoplasmosis on human behavior observed in past 25 years, its effect on attraction to the smell of highly diluted cat urine in men, explained 9.8% of the between-subjects variability in this trait (Flegr et al., 2011).

Conclusions

Our study confirmed the existence of specific differences in sexual behavior, desires, and preferences between *Toxoplasma*-infected and *Toxoplasma*-free subjects. The character of these changes, that is, the higher attraction to bondage, violence, and, in men, to masochism and raping supports our hypothesis about

the coactivation of sex-related and fear-related medial amygdala circuits in humans. It must be stressed that the *Toxoplasma* infection explains only small part of the variability in BDSM-associated traits. It was shown that sensitivity of current serological tests is not ideal and that even in populations of young seronegative subjects, 5–15% individuals are, in fact, *Toxoplasma* infected (Flegr & Havlíček, 1999; Flegr, Hrdá, & Kodym, 2005). In older age strata, the seroprevalence of toxoplasmosis decreases (Kolbeková, Kourbatova, Novotná, Kodym, & Flegr, 2007), which suggests that the frequency of false negatives among older people is probably much higher. It could be speculated that the false negatives, that is, the subjects with the oldest infections and therefore lowest concentration of anamnestic anti-*Toxoplasma* antibodies, could be responsible for certain BDSM traits in seemingly *Toxoplasma*-free subjects. A more probable explanation, however, is that the sexual arousal by danger, fear, and so on could have a common neurophysiological mechanism (possibly the coactivation of sex-related and fear-related circuits in amygdala), however this coactivation could have various independent causes and *Toxoplasma* just (mis)uses this property of the mammal brain for manipulation with behavior of their intermediate hosts.

Acknowledgments

We would like to thank Lenka Příplatová for her help with preparing the electronic questionnaire; Charlie Lotterman, Martin Hůla, and Julie Nováková for their help with English version of this article; and Alena Černíková for her help with statistical analysis.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The authors' work was supported by the Charles University of Prague (GAUK 269215, Grant UNCE 204004), the Grant Agency of the Czech Republic (Grant no. 16-20958 S), and by the project "National Institute of Mental Health (NIMH-CZ)" (Grant number ED2.1.00/03.0078; and the European Regional Development Fund). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of this article.

Supplementary Materials

The online [appendices/data supplements/etc.] are available at http://evp.sagepub.com/supplemental.

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