Toxoplasma gondii is a protozoan parasite infecting about 30% of our population. After a short phase of acute infection, the parasitosis turns into the lifelong latent stage which is usually considered asymptomatic. However, in the studies performed by our research team, latent toxoplasmosis was found to have specific effects on personality, behavior, morphology and physiology. Interestingly, in many aspects, these effects were clearly gender-different.

My thesis was motivated by results of previous questionnaire studies which found toxoplasmosis to have opposite influence on men's and women's personality traits warmth, conscientiousness and vigilance measured by Cattell’s 16 Personality Factor Questionnaire (Flegr et al. 1996, 1999, 2000, Flegr and Havlíček 1999, Flegr and Hrdý 1994). Both infected women and men were also found to score lower in novelty seeking (Skallová et al. 2005, Flegr et al. 2003).

The result of lower novelty seeking was confirmed by the first study performed with my contribution (Novotná et al. 2005). Moreover, this study showed that regarding novelty seeking, similar changes were observed in subjects infected by cytomegalovirus. This was interpreted as evidence for the hypothesis that behavioral/personality shifts induced by latent toxoplasmosis could be nonspecific changes, caused by mild chronic brain infections. Lower novelty seeking is thought to be associated with increased dopamine concentration (previously documented in Toxoplasma-infected rodents) and dopamine levels have been reported to be elevated by inflammatory processes. As I discuss in the introductory part of my thesis, this “inflammation hypothesis” is interesting, but it needs to be confirmed and elaborated by future research.

The previous questionnaire results of gender differences in Toxoplasma-induced personality shifts were extended by our new studies to include results based on behavioral observations and experimental data. In the first study by Lindová et al. (2006), infected men were found to have lower values in behaviorally assessed warmth, self-control and showed less clothes tidiness than uninfected men. Infected women typically showed a trend in the opposite direction being significant in the variable self-control assessed by “real life” experiments (infected women scored higher than uninfected women). Since the validity of questionnaire-based studies on links between biological and psychological variables has often been questioned, these results using behavioral observations and experiments represented a very important step in research on the topic.

A further goal of our research was to analyze behavior of infected and uninfected subjects in experimental games. Two experimental games were used – the Dictator Game and the Trust Game. Both being based on the principle that one subject of a randomly assigned couple divides a certain amount of money received from the experimentator between himself and the second player, the two games differed as for the possibility to show reciprocity between players. While in the Dictator Game, no reciprocity was possible because the second player was passive, the Trust Game included an active response of the second player to the “investment” of the first player. A generous act of the first player could have been rewarded by a return of a greater amount of money from what the second player “earned” from the investment (earning = 3 x investment). In the non-reciprocal Dictator Game, both infected men and women were less generous to their opponents/playmates than uninfected men and women. However in the reciprocal Trust Game, the Toxoplasma-induced shift was affected by gender. While infected men returned less money to the first player than uninfected men, infected women behaved rather more generously and returned slightly more money to the first player. Because enhanced pro-social behavior (i.e. mutual support, empathy, affiliation) is thought to be a typical characteristic of women’s stress coping, whereas men cope with stress...
with rather antisocial strategies, we proposed that latent toxoplasmosis could induce mild long-term stress on infected subjects (Lindová et al. submitted).

Two other studies were focused on morphological differences between infected and uninfected subjects and they both point to the role of testosterone. The study by Flegr et al. (2005) reports on our finding of a decreased 2D:4D ratio of infected men and a trend in the same direction observed for women and a greater body height of infected men. The 2D:4D ratio is thought to be negatively, and height is thought to be positively associated with testosterone levels. In the later study by Hodková et al. (2007), infected men were rated as more dominant and masculine from facial photographs. This is another indirect sign of increased testosterone levels in infected subjects.

In our most recent work, we directly estimated testosterone levels in infected and uninfected subjects (Flegr et al. submitted a). Surprisingly, a gender difference appeared even on this physiological level with infected men having a non-significantly higher level of testosterone than uninfected men and infected women having a significantly lower level of testosterone than uninfected women. Going back to results of the two above mentioned studies on testosterone-associated morphological changes, it is striking that all significant results were obtained for men only.

As I discuss in the introductory part of my thesis, there are also other hormones but testosterone that deserve attention with regard to the mechanism of the effect of Toxoplasma on behavior. As is suggested Lindová et al. in press, 2D:4D could be a marker of female sex hormones in addition to male sex hormones. Female steroids, in particular estrogens, are likewise interesting considering their role in the immune response and stress response.

In my thesis, I discuss these particular results once again in the context of available evidence applied to three theories of the mechanism of gender different effects of latent toxoplasmosis, namely a) the theory based on gender differences in inflammatory processes, b) the theory considering Toxoplasma-induced changes as consequences of altered testosterone levels and c) the "stress theory" based on the assumption that Toxoplasma could qualify as a chronic stressor and on evidence regarding gender-different stress response/copng styles. Although the stress theory seems to explain the most findings of the psychological nature, its physiological basis remains on the level of speculations. On the other hand, the repeated finding of testosterone changes in infected subjects does not appear to have an evident counterpart in observed psychological shifts. Therefore, it is important that more research be done on this topic, preferably also involving other research teams' work.

In addition to the main line of my PhD research briefly summarized above, these mentioned studies brought several side results, contributing to our knowledge in related scientific fields and sometimes also raising new questions. So infected subjects of both genders were found to differ not only in the testosterone-associated 2D:4D ratio, but also in additional 17 out of 30 anthropometric parameters (e.g. digit lengths, hand length, wrist breadth, ankle breadth). This finding was not expected and awaits future explication (Flegr et al. 2005).

We also contributed to the fast growing knowledge on 2D:4D correlates. Lindová et al. in press found right hand 2D:4D of women to be negatively correlated with emotional stability and social boldness, and positively with privativeness from Cattell's 16 PF. As related research from other authors was based on the Five Factor Model or Eysenck's three factor model, our results represent an important extension of previous work and even seem to resolve some previous inconsistencies. Moreover, as toxoplasmosis shifts the finger lengths including the 2D:4D ratio, in an additional paper by Flegr et al. (submitted b) we refer to the possibility of Toxoplasma-infection status being an important confounding factor in the 2D:4D research.

References: