

Influence of chronic toxoplasmosis on some human personality factors

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Abstract. An effect of parasites on host behaviour was tested on the toxoplasma-human model. Three hundred and thirty-eight (338) people were assessed with Cattell's personality questionnaire and then tested for *Toxoplasma gondii* infection with a delayed type hypersensitivity test for *Toxoplasma*. A highly significant correlation between chronic toxoplasmosis and two personality factors (*G*- Low Superego Strength and *L*- Protension) was found ($p = 0.0032$ and 0.0020 , respectively). A correlation of the intensity of the personality factor-shifts with the duration of the infection (estimated from antibody titer) suggests that toxoplasmosis induces the shift in human personality, rather than the personality factors *G* and *L* influence an acquisition rate of *Toxoplasma gondii* infection.

The effect of parasitism on host behaviour is being demonstrated in a growing number of host-parasite systems. The induced behavioral patterns often promote transmission of the parasite. One hypothesis suggests that such modification of host behaviour is a sophisticated product of parasite evolution aimed at host manipulation rather than an accidental byproduct of other physiological activities of the parasite (Barnard and Behnke 1990, Dawkins 1982). Among parasitic protozoa from the suborder Eimeriina, the phenomenon has been observed in *Sarcocystis* (Hoogenboom and Dijkstra 1987), *Eimeria* (Kavaliers and Collwell 1982) and *Toxoplasma gondii* Nicolle et Manceaux, 1906 (Hay et al. 1985). The last organism is an intestinal coccidian of felids with an unusually wide range of intermediate hosts, including humans. After an acute phase of infection (promoted by tachyzoites), in *Toxoplasma*-infected subjects cysts are formed mainly in neural and muscular tissues. The parasites (bradyzoites) inside the cysts usually cause little or no harm in immunocompetent individuals and probably persist as viable parasites for the life of the host (Remington and Krahenbuhl 1982). The transmission of the parasite from the intermediate to the definitive host is mediated by carnivorousness. Since sexual reproduction of *Toxoplasma* can be accomplished only in the feline, there might be a strong selection pressure on the parasite to evolve a mechanism to manipulate intermediate host-behaviour so as to favour predation by felines. A high prevalence of lifelong toxoplasmosis (about 32% of pregnant women in New York City, 22% in London and 84% in Paris (Desmonts and Couvreur 1974)) offers an opportunity to study the possible influence of the parasitism on human behaviour by random screening of normal population. Here we studied an effect of chronic toxoplasmosis on human personality in an experimental set of 338 humans.

MATERIALS AND METHODS

Subjects. The study was carried out in the Faculty of Science, Charles University, Prague. Data were collected for a period of 14 months (1992–1993). The experimental set contained 195 men and 143 women, mostly zoological departments staff and biology students. The main advantage of this experimental set is its relative homogeneity. On the other hand the extrapolation of our results on different sets should be done carefully. All subjects gave their informed consent before they were accepted for the study.

Personality test. Cattell's sixteen factor questionnaire (form A) (Cattell 1970) was used for the characterization of personalities. This questionnaire is widely used in personality studies in the Czech Republic. It covers sixteen personality factors (Table 1). The main advantage of this test is that it contains only one hundred and eighty-seven (187) questions. Therefore, it can be completed by most subjects within one hour. With the exception of parasitologists, practically all subjects were tested psychologically before the results of the toxoplasmosis test were known.

Immunological test for chronic toxoplasmosis. As the chronic toxoplasmosis we understand here the presence of anti-*Toxoplasma* immunity in human subjects without any clinical symptoms of acute toxoplasmosis. The existence of specific immunity was assessed by intradermal delayed hypersensitivity test (IDHT) (Feldman 1954). The test was performed using *toxoplasmin* (SEVAC, ÚSOL Prague) as the antigen and shame injection of pure solute as the negative control. Positive reactions were of the delayed tuberculin type and were measured at 48 h following antigen administration. The large-scale use of the toxoplasmin skin test in population surveys has yielded excellent agreement between the results of this test and the presence or absence of humoral antibody (Remington and Krahenbuhl 1982). The ability to elicit DH to toxoplasma antigens in man appears to require months to years after initial infection to develop, so it appears to be most useful in the diagnosis of chronic infection (Remington and Krahenbuhl 1982).

In those persons giving their consent (41 subjects), the presence of anti-*Toxoplasma* antibodies was evaluated by an indirect fluorescent antibody test, IFAT, (Goldman 1957) using the IFR kit prepared in our lab (Kramář et al. 1963). There was a perfect agreement between the results of IDHT and IFAT.

Statistics. The BMDP (Dixon 1990) program was used for all of the following statistical testing: The Hotelling *t*-test was used for comparing the sets of *Toxoplasma*-infected and *Toxoplasma* free subjects (P3D). A Two-way analysis of variance ANOVA (P7D) was used to study the effects of toxoplasmosis, age and toxoplasmosis-age interactions on personality factors. Discriminant analysis (P7M) was used for personality factor-based diagnosis of toxoplasmosis and for stepwise covariance analysis of personality factors. Kendall nonparametric range correlation test (P3S) was used to estimate the correlation between the anti-*Toxoplasma* antibodies level and the amount of personality factors-shift.

RESULTS

Personality profiles of two groups of subjects, *Toxoplasma* infected ones (TI) (56 men and 34 women) and *Toxoplasma* free ones (TF) (139 men and 109 women) were compared using the Hotelling *t*-test. No difference in personality profiles between TI and TF groups was

detected when women and men were considered together ($p = 0.241$) or when only TI and TF women were compared ($p = 0.204$). However, a highly significant difference was detected when the personality profiles of TI and TF men were compared ($p = 0.025$). Of the 16 factors estimated by the Cattell's questionnaire the four factors which apparently caused the difference are marked in Table 1. Because of this result, all the following testing were performed only with the men set.

Some personality factors as well as the frequency of toxoplasmosis vary with the age of a subject. To determine whether the differences observed were the result of causal relationships between toxoplasmosis and the personality factors or whether it was only a false correlation resulting from the effect of age, a Two-way ANOVA was performed. This analysis showed that for factors *G* and *L* and possibly *A* and *Q₃* as well, the toxoplasmosis not age was responsible for the observed differences (Fig. 1).

Table 1. List of sixteen personality factors that can be monitored by Cattell's questionnaire. The names and characteristics in the left column hold for persons with low value of the factor, those in the right columns for persons with the high value of the factor. The raw data for any person were standardized with respect to his/her age and sex. An asterisk ($p < 0.05$) and two asterisks ($p < 0.01$) designate the property which predominated among the toxoplasma-positive people.

A -	SIZOTHYMIA *	reserved, detached, critical	AFFECTOTHYMIA	warmhearted, outgoing, easygoing
B -	LOW INTELLIGENCE		HIGH INTELLIGENCE	
C -	EGO WEAKNESS	affected by feelings, emotionally less stable	HIGH EGO STRENGTH	emotionally stable, mature, faces reality, calm
E -	SUBMISSIVENESS	obedient, mild, easily led, docile	DOMINANCE OR ASCENDANCE	assertive, aggressive, competitive, stubborn
F -	DESURGENCY	sober, taciturn, serious	SURGENCY	enthusiastic, heedless, happy-go-lucky
G -	LOW SUPEREGO STRENGTH **	disregards rules, expedient	SUPEREGO STRENGTH OR CHARACTER	conscientious, persistent, moralistic, staid
H -	THRECTIA	shy, timid, restrained, threat-sensitive	PARMIA	adventurous, "thick-skinned", socially bold
I -	HARRIA	tough-minded, rejects illusions	PREMSIA	tender-minded, sensitive, dependent
L -	ALAXIA	trusting, accepting conditions, tolerant	PROTENSION **	suspecting, jealous, dogmatic
M -	PRAXERNIA	practical, has "down to earth" concerns	AUTIA	imaginative, bohemian, absent-minded
N -	NAIVETÉ	forthright, unpretentious	SHREWDNESS	astute, worldly, polished
O -	UNTROUBLED ADEQUANCY	self-assured, placid, secure, complacent	GUILT PRONENESS	apprehensive, self-reproaching, insecure
Q ₁ -	CONSERVATISM OF TEMPERAMENT	conservative, respecting establishments	RADICALISM	experimenting, liberal, analytical, free-thinking
Q ₂ -	GROUP DEPENDENCY	sociably group dependent, "joiner"	SELF-SUFFICIENCY	self-sufficient, resourceful, prefers own decisions
Q ₃ -	LOW SELF-SENTIMENT INTEGRATION *	uncontrolled, lax, follows own urges	HIGH STRENGTH OF SELF-SENTIMENT	controlled, exacting will power, socially precise
Q ₄ -	LOW ERGIC TENSION	relaxed, tranquil, torpid, unfrustrated	HIGH ERGIC TENSION	tense, frustrated, driven, overwrought, fretful

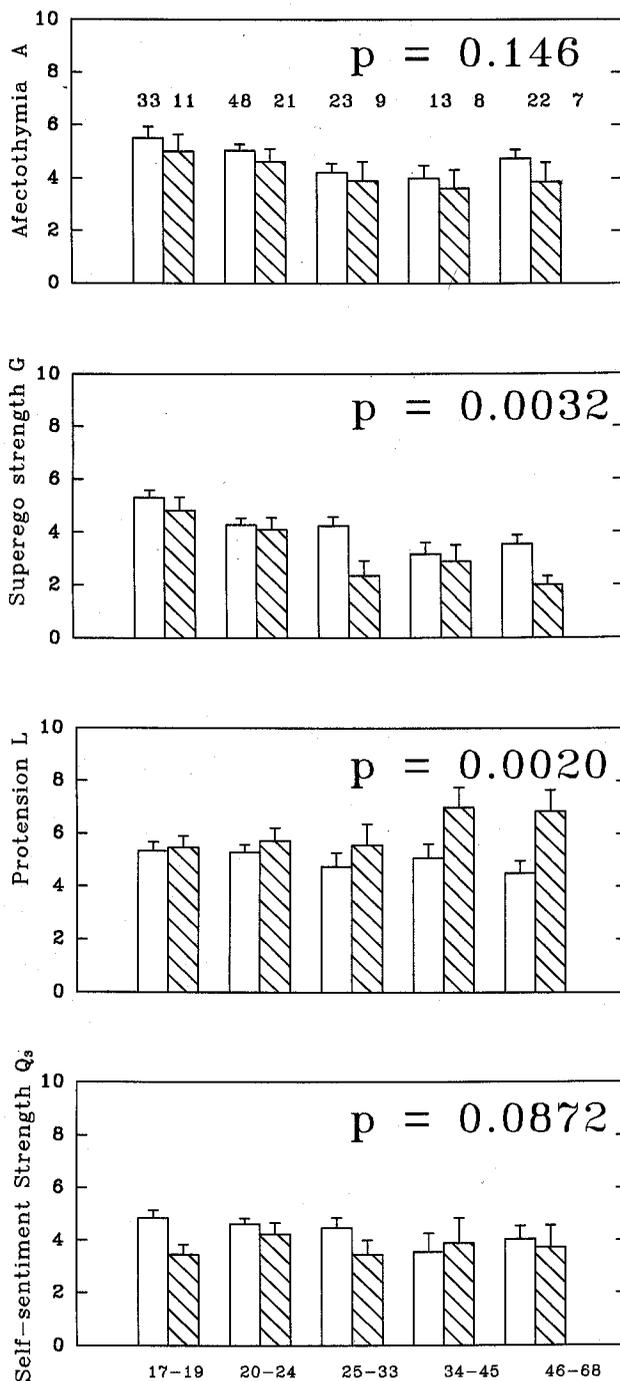


Fig. 1. Effect of toxoplasmosis and age on four personality factors estimated in 195 male subjects by Two-way analysis of variance (BMDP, program P7D). The effects of toxoplasmosis, age and toxoplasmosis-age interactions were tested. Only the tail probabilities for toxoplasmosis effects are given. Open and crosshatched bars show the means with standard errors of a particular personality factor for different age classes of *Toxoplasma* negative and positive subjects, respectively. The cut points for the age classes correspond to those used for the age standardization of row data obtained by Cattell's questionnaire. The numbers of subjects in groups on the graph were indicated on the upper plot. The equality of variances for the factors listed was confirmed by the Levene's test.

The possibility that some of the personality factors changed because of their correlation with another toxoplasmosis-influenced factor rather than their correlation with toxoplasmosis was studied by a discriminant analysis. This statistical method was primarily designed for the classification of objects into previously defined groups. It can also be used for estimating the correlation effects among the factors by an approach based on analysis of covariance (Bouška et al. 1990). During a stepwise process of incorporating factors *A*, *G* and *L* into a classification function, it appears that factor *A* (Sizothymia) was strongly influenced by factor *L* (Protension). By incorporating the factor *L*, the F value for factor *A* decreased from 2.90 to 2.40, while by incorporating factor *A*, the F value for *L* decreased from 7.37 to 6.84. Factors *G* and *L*, however, were entirely independent (after incorporation *L*, the F value for *G* only decreased from 6.91 to 6.90).

Discriminant analysis performed on the basis of Cattell's personality factors proved to be able to sort out group of subjects suspected of having toxoplasmosis. In the group of 14 subjects classified as *Toxoplasma* positive on the basis of the factors *G* and *L*, the frequency of toxoplasmosis was 64% (*a priori* probability, the frequency in the unsorted population was 28.7%). When factors *F* and *Q*₂ were included into classification function, the frequency of correctly diagnosed toxoplasmosis increased up to 73.7%.

Among 176 subjects classified as *Toxoplasma* negative the frequency of correct diagnosis was 76.1%. That differs only slightly from *a priori* probability 71.3%. Such results could be expected if the *Toxoplasma* infection antecedes the shift in the personality factors.

While a relatively recently acquired toxoplasmosis (months) can be effectively detected by immunological test (Krahenbuhl and Remington 1982), the transformation of the human personality (and the manifestations of the changes) evidently could be a long term process. This offers a possibility to test whether the toxoplasmosis induces the personality factor-shift or whether some personality factors influence the probability of being infected by *T. gondii*. Early infections can be recognized by higher level of specific antibodies (Krahenbuhl and Remington 1982). For 24 infected male subjects the data from indirect fluorescent antibody test (IFAT) were available. Using a nonparametric Kendall rank correlation test, a highly significant correlation ($k = -0.573$, $p = 0.00009$) occurred between the levels of the antibodies measured by IFAT and the amount of personality factors-shifts, quantified with the values of posterior probabilities for group TI obtained by discriminant analysis (Fig. 2). The existence of such correlation suggests that the personality factor-shift develop after the *T. gondii* infection.

DISCUSSION

Our results suggest that in human males a strong correlation exists between certain personality factors and chronic toxoplasmosis (monitored by IDTH). The nature of critical personality factors (see Table 1) and a positive correlation between the amount of personality factors-shift and the antibody titer-based estimates of the duration of the infection suggests that the toxoplasmosis induces the shift in human personality, rather than the personality factors influence an acquisition rate of *Toxoplasma gondii* infection.

The positive reaction in IDHT suggests the existence of cellular anti-*Toxoplasma* immunity. The presence of the immunity is mostly interpreted to be a marker of acute or chronic toxoplasmosis (Krahenbuhl and Remington 1982). Experience with AIDS patients suggests that the frequency of latent human toxoplasmosis may be quite similar to the frequency of *Toxoplasma*-immune subjects. However, it still must be clarified as to whether the personality factors-shift was induced by latent chronic toxoplasmosis or whether it is only triggered by the acute stage of the infection.

The results from the ANOVA and from *t*-tests suggest that personality factors *G* and *L* are, and the *A* and *Q*₃ might be, shifted in TI persons. On the other hand, in discriminant analysis another group of factors (*G*, *L*, *F* and *Q*₂) proved to be most suitable for identification of TI subjects. This discrepancy can be explained by the differences in the mathematical backgrounds of these two met-

hods. Discriminant analysis includes a stepwise covariance analysis. In every step, the computed F-to-enter values are affected by the variables already present in the classification function. When a strong correlation exists between two variables (e.g., factor *A* and *L*) only the one with the higher F value might be entered classification function. On the other hand, when there is no correlation among variables (e.g., factors *G*, *L*, *F* and *Q*₂), all might be entered the function, no matter what their F values in the step zero of discriminant analysis (or in *t*-tests). Our results suggest that toxoplasmosis influenced the factors *G*, *L*, *F* and *Q*₂. The factors *A* and *Q*₃ might also be shifted in TI male subjects. Their shifts, however, were caused by their correlation with factors *G* or *L*, rather than with toxoplasmosis.

The personality factors-shift was demonstrated only in men. It is possible that women are more resistant to manipulation by the parasite. Another explanation is that our technique of evaluating human personality factors should be modified for the female population. It is well known (Mohan and Chopra 1986, Steiner 1987) that results obtained with a personality questionnaire in women vary when the tests are performed in different stages of the menstrual cycle. It can be assumed that similar set of personality markers (biologically based ones) could be influenced by hormone levels as well as by toxoplasmosis. Therefore, it will be important to perform further studies in women through all menstrual cycle stages and to collect the data from all experimental subjects in the same stage.

The influence of severe forms of acute toxoplasmosis on human personality has been reported by clinicians (Burkinshaw et al. 1953, Minto and Roberts 1959, Ladee et al. 1966, Freytag and Haas 1979). Typically, however, the effects of acute toxoplasmosis on immunocompetent patients are mild. Chronic toxoplasmosis is usually considered asymptomatic (Remington 1974). In fact, only a negligible fraction of infected people ever learn that they are parasitized by *Toxoplasma gondii*. It seems reasonable to expect that the observed psychological symptoms of toxoplasmosis only indirectly reflect some activities of the parasite. One can only speculate, as to whether these activities are connected with an attempt (in the human host a nonproductive one) of the parasite to manipulate the host behaviour, or are only byproducts of a nonspecific worsening of the quality of the host life. Theoretically, infected subjects might suffer more frequent or more severe diseases because of an interference of the parasite with their immune system (Remington and Krahenbuhl 1982). Such effects of toxoplasmosis, however, have never been reported.

The apparent influence of *T. gondii* on the personality of human males was unexpected and pronounced. The nature of the shift in human personality following *Toxoplasma* infection can hardly be considered desirab-

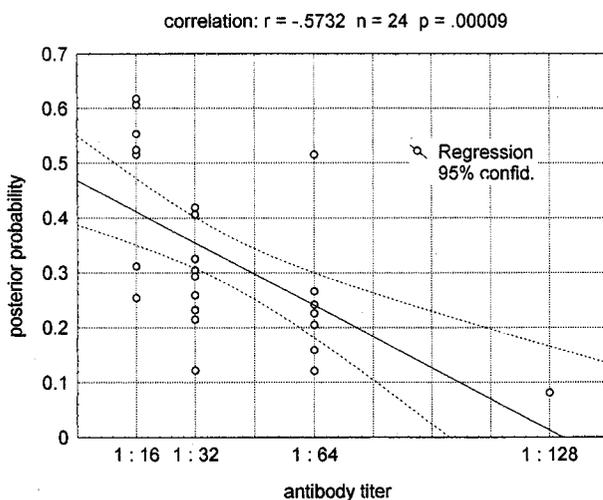


Fig. 2. Correlation of the level of anti-*Toxoplasma* antibodies with the amount of personality factor shift. Each point corresponds to a single *Toxoplasma* infected subject. x-axis: antibody titer measured by IFAT, y-axis: posterior probability of having toxoplasmosis computed on the basis of Cattell's personality factors by discriminant analysis. The value of Kendall rank correlation coefficient, $k = -0.573$ confirms the existence of the correlation on the level $p = 0.00009$.

le. It might seem anecdotal that in a group of 29 *Toxoplasma* negative professors from our experimental set there are 10 present or past decision-makers (heads of department, vicedeans and deans) while among 14 *Toxoplasma* positive professors there is only a single head of department.

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REFERENCES

- BARNARD C. J., BEHNKE J. M. (Eds.) 1990: Parasitism and Host Behaviour. Taylor and Francis, London, New York, Philadelphia, 332 pp.
- BOUŠKA V., DELANO J. W., MASLOWSKÁ H., ŘANDA Z. 1990: Discriminant analysis of the moldavite data set. Acta Univ. Carol. -Geol. 3: 243-258.
- BURKINSHAW J., KIRMAN B. H., SORSBY A. 1953: Toxoplasmosis in relation to mental deficiency. Brit. Med. J. 702: 1-6.
- CATTELL R. B. 1970: Handbook for the sixteen personality factors questionnaire (16PF). Institute for Personality and Ability Testing, Champaign, 115 pp.
- DAWKINS R. 1982: The Extended Phenotype: the Gene as the Unit of Selection. Freeman, London, 307 pp.
- DESMONTS G., COUVREUR J. 1974: Congenital toxoplasmosis. A prospective study of 378 pregnancies. N. Engl. J. Med. 290: 1110-1116.
- DIXON W. J. 1990: BMDP Statistical Software. Univ. Calif. Press, Berkeley, 1385.
- FELDMAN H. A. 1954: Laboratory methods in current use for the study of toxoplasmosis. In: E. B. Streiff (Ed.), Advances in Ophthalmology, Vol. III, Lausanne Bibliotheca Ophthalmologica Fasc. 39, pp. 1-11.
- FREYTAG H. W., HAAS H. 1979: Zur Psychopathologie der erworbenen Toxoplasmose. Nervenarzt 50: 128-131.
- GOLDMAN M. 1957: Staining *Toxoplasma gondii* with fluorescein-labelled antibody. I. The reaction in smears of peritoneal exudate. J. Exp. Med. 105: 549-556.
- HAY J., AITKEN P. P., AMOTT M. A. 1985: The influence of congenital toxoplasma infection on spontaneous running activity of mice. Z. Parasitenkd. 71: 459-462.
- HOOGENBOOM I., DIJKSTRA C. 1987: *Sarcocystis cernae*: a parasite increasing the risk of predation of its intermediate host, *Microtus arvalis*. Oecologia 74: 86-92.
- KAVALIERS M., COLLWELL D. D. 1982: Parasitism, opioid systems and host behaviour. Adv. Neuroimmun. 2: 287-295.
- KRAHENBUHL J. L., REMINGTON J. S. 1982: The immunology of *Toxoplasma* and toxoplasmosis. In: A. J. Mahmiás, J. O'Reilly (Eds.), Immunology of Human Infections, Part I. Plenum Publishing Corporation, New York, pp. 356-421.
- KRAMÁŘ J., ČERNÁ Ž., CHALUPSKÝ J. 1963: Immunofluoreszenzreaktionen in der serologischen Diagnostik der Toxoplasmose. Zbl. Bakteriologie, Parasitenkd. Infekt. Hyg. 1 Orig. 193: 523-534.
- LADEE G. A., SCHOLTEN J. M., POSTHUMUS MEYES F. E. 1966: Diagnostic problems in psychiatry with regards to acquired toxoplasmosis. Psychiat. Neurol. Neurochir. 69: 65-82.
- MINTO A., ROBERTS F. J. 1959: The psychiatric complications of toxoplasmosis. Lancet, June 6: 1180-1182.
- MOHAN V., CHOPRA R. 1986: A study of personality variation in women before and after menstruation. Pers. Individ. Diff. 7: 127-128.
- REMINGTON J. S. 1974: Toxoplasmosis in the adult. Bull. New York Acad. Med. 50: 211-227.
- REMINGTON J. S., KRAHENBUHL J. L. 1982: Immunology of *Toxoplasma gondii*. In: A. J. Nahmiás, J. O'Reilly (Eds.), Immunology of Human Infection, Part II. Plenum Publishing Corporation, New York, pp. 327-371.
- STEINER M. 1987: The effects of gonadal hormones on brain and behaviour. Prog. Neuropsychopharmacol. Biol. Psychiatry 11: 115-119.

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