acta ethol (2010) 13:57–62
DOI 10.1007/s10211-010-0075-4

ORIGINAL PAPER

The association between disgust, danger and fear of macroparasites and human behaviour

Pavol Prokop · Jana Fančovičová

Received: 27 March 2009 / Accepted: 11 April 2010 / Published online: 5 May 2010

Abstract Evolutionary explanations of disgust propensity propose that disgust is an adaptation which helps us to decrease the likelihood of being infected by pathogens. To test this hypothesis, we examined human fear, disgust and self-perceived danger as a response on colourful pictures of disease-relevant and disease-irrelevant invertebrates. Furthermore, we also examined a possible link between these variables and human anti-parasite behaviour. We found that participants clearly distinguished between disease-relevant and disease-irrelevant group of animals, and that females always scored higher than males. Moreover, there were associations between ratings of fear, disgust and danger and human anti-parasite behaviour. Our results support the hypothesis that human emotions and behaviours are shaped by natural selection.

Keywords Parasites · Natural selection · Human behaviour · Disgust · Fear

Introduction

Disgust is an emotion that can be related to avoidance of certain animals, ill humans, faeces, vomit, sexual substances and other harmful substances or events (Rozin et al. 2000). Magnetic resonance imaging studies have proposed a specific neurological substrate for perceiving disgust, located in the anterior insular cortex (Phillips et al. 1997). This suggests that disgust propensity has long evolutionary origin with possible adaptive significance for animals including humans.

Rubio-Godoy et al. (2007) distinguish two stages of disgust: a priori disgust is the first stage which involves early detection of an infectious environmental threat. Examples include defensive behaviour such as avoiding slimy or dirty objects, keeping away from sites that pose health risks, etc. A posterior disgust involves reactions and behaviours after contact or after early penetration of disgust-evoking stimuli in the organism's body. Typical examples are vomiting, nausea, diarrhoea, etc. Both stages revolve around elimination of disgust-evoking objects that would be potentially harmful to an individual. Several researchers therefore propose that disgust may be an adaptive strategy to decrease a likelihood of being infected by pathogens (Curtis et al. 2004; Rubio-Godoy et al. 2007). Although disgust is apparently distinguishable from fear (Curtis and Biran 2001), both of them are compatible. While disgust involves a suspension of activity, fear heightens activity in preparation for fight or flight (Phillips et al. 1998).

Several works suggest that disgust evolved to help humans avoid diseases. Curtis et al. (2004) in their Web-based experiment asked participants to rate how disgusting pairs of photos were similar in appearance, but where the disease relevance of each picture was experimentally manipulated. As expected, all of the images with disease relevance scored as more disgusting than those without. Mean disgust scores were consistently higher in women. Humans who think themselves more vulnerable to disease transmission, have greater aversive responses against physically disabled individuals (Park et al. 2003), toward older adults (Duncan and Schaller 2009), immigrants

P. Prokop (✉)
Institute of Zoology, Slovak Academy of Sciences,
Dúbravská cesta 9,
84506 Bratislava, Slovakia
e-mail: Pavol.Prokop@savba.sk

J. Fančovičová
Department of Biology, University of Trnava,
Priemyselná 4, P.O. Box 9, 91843 Trnava, Slovakia

(Faulkner et al. 2004) or toward disease-relevant animals (Prokop et al. 2010). Physical contact with all these groups of people increases the probability of transmission of a novel, infectious disease. Thus, the *behavioural immune system* that is defined as a set of mechanisms that allow individuals to detect the potential presence of parasites in objects (or individuals) act to prevent contact with potentially contagious objects (or individuals; Schaller 2006; Schaller and Duncan 2007). Further support for the adaptive significance of disgust comes from studies examining disgust and fears of animals that are or are not potentially dangerous in terms of dangerousness or disease transmission. Davey et al. (1998) have shown that people perceive disease-relevant (e.g. cockroaches, worms, etc.) and predatory animals (e.g. like lions, bears, sharks, etc.) differently than non-predatory or disease-irrelevant animals like rabbits, wild birds and others. Curtis and Biran (2001) report that one of most frequently reported disgust eliciting animals are parasitic invertebrates well known as vectors of viral and bacterial infections (e.g. lice, ticks, fleas, flies) and worms that cause taeniasis or dracunculiasis. Bjerke et al. (2003) similarly found that participants in Norway rated disgust of fear irrelevant animals like squirrels, butterflies or hedgehogs more positively than harmful animals like rats, mosquitoes or wasps.

Results of these studies can be interpreted by the biological preparedness hypothesis (Seligman 1971). This hypothesis proposes that these animals presented a critical danger for our ancestors, hence predisposed them to rapid learning processes. For example, quick reactions to snake-induced stimuli became evolutionarily selected for (Öhman et al. 2007).

As almost all known human-specific parasites have been found in ancient faeces (Gonçalves et al. 2003), avoiding harmful animals like macroparasites or disease-relevant insects like mosquitoes should have a selective advantage for humans because such invertebrates are hazardous (reviewed by Macpherson 2005). For example, parasitic worms debilitate an estimated third of the world's population (Warren et al. 1991). One to two million people die from malaria that is transmitted through mosquitoes annually (Crompton 1999; Sachs and Malaney 2002). Annually, about 85,000 people in Europe are infected with Lyme borreliosis that is transmitted by ticks (Lindgren and Jaenson 2006).

Surprisingly, there are no works examining associations between disgust propensity and human anti-parasitic behaviour. In this study, we examined (1) whether all invertebrates are perceived similarly, or whether there are differences in terms of participants' self-perceived fear, disgust and danger elicited by colour pictures of invertebrates is associated with potential disease risk. Furthermore, we also investigated (2) whether this level of disgust, fear and danger associated with specific behaviours could be interpreted as human anti-parasitic response.

Methods

The study was conducted between January and February 2009. The sample of participants (105 males and 96 females) consists of children from primary and secondary school level. Selection of participants was not intentional, but was based on teachers' willingness to participate on the research in accessible schools (n=2) in which the authors had personal contacts with directors. If the teacher agreed, the questionnaire was administered to all participants in selected classes irrespective of the participants' attitudes towards animals. Age of participants ranged from 8 to 15 years (mean=11.92, SE=0.14). The participants were asked (1) for their age, (2) for their sex and (3) if they kept any animals as pets or farm animals.

We projected 25 colour pictures [five disease-relevant adult insects, five ectoparasites, five endoparasites, five disease-irrelevant adult insects and five insect larvae/earthworm] in lecture halls (see Appendix A for complete list of species). The first three groups of animals were risky to humans in terms of decreased immunity and/or health problems and the latter two groups served as controls. Disease-irrelevant adult insects were controls for disease-relevant adult insects and ectoparasites and insect larvae/earthworm were controls for endoparasites. We adjusted picture sizes to a standard body length. Pictures had similar contrast and brightness. The pictures were presented in random order. Each picture was presented for 1 min. During this time, participants rated fear, disgust and how dangerous they thought the animal is in nature, each on a five-point scale (1 = not at all, 5 = extremely dangerous).

For measuring human behaviour related with parasite avoidance, a simple Parasite Avoidance Questionnaire (PAQ) was used; it consisted of 13 developed questions. Each question was answered on a four-point scale (e.g. 1 = never, 4 = very frequently). The content of questions reflects risky behaviours associated with parasite transmission. More details about content of these questions can be found in Table 1. Because reliability of participants' responses was not satisfactory (Cronbach's alpha=0.41), we excluded six items that did not correlate with others which resulted in higher reliability (Cronbach's alpha=0.58). Remaining items were focused on caressing dogs and cats (four items), hand washing (after arrival to home and before eating food; two items) and helping the homeless (one item). The reliability was relatively low (critical value is 0.7, see Nunnaly 1978), thus some caution must be made when interpreting these data. However, other researchers also reported alpha coefficients in the rage 0.43–0.95 (e.g.

Table 1 Framework for the Parasite Avoidance Questionnaire (PAQ)

Anti-parasite behaviour	Reason for inclusion (source example)	Number of questions
Personal hygiene[a], washing fruits and vegetables[b]	Washing vegetables, fruits and hands prevents parasite transmission such as hepatitis, toxoplasmosis, diarrhoea, bacterial and viral pathogens, etc. (Brundage and Fitzpatrick 2006, Curtis and Cairncross 2003, Rabie and Curtis 2006)	5
Avoidance of eating undercooked meat[b]	Transmission of food-borne diseases like taeniasis, toxoplasmosis, etc. (Fan et al. 1992, Smith 1994, Dorny et al. 2009, Dubey 2009)	1
Avoiding contact with companion animals	About 60 parasite species can be transmitted from companion animals to humans. Examples include *Giardia*, *Toxoplasma*, *Ancylostoma*, *Toxocara*, etc. (reviewed by Macpherson 2005, Palmer et al. 2008, Ramirez et al. 2004, Dubey and Jones 2008)	4
Killing blood sucking insects[b]	Blood sucking insects are vectors of parasitic diseases like malaria, trypanosomes, elefantiasis, filariasis, etc. (Chernin, 1977, reviewed by Schmidt and Roberts 1989, Sachs and Malaney 2002)	2
Homeless avoidance	Homeless are hosts of ectoparasites (lice, fleas, ticks) and infectious diseases like tuberculosis, typhus, etc. (Brouqui and Raoult 2006, Bonilla et al. 2009, Hwang et al. 2008, Reeves et al. 2008)	1

[a] Some items were removed due to low correlation with other items (see "Methods" for more details)

[b] All items were removed due to low correlation with other items (see "Methods" for more details)

Goetz and Shackelford 2009). High mean scores for PAQ meant that participants performed parasite avoidance behaviours more frequently.

Statistical analyses

To examine possible differences in fear, disgust and danger ratings between five animal groups, we computed a multivariate ANOVA including the five animal groups (disease-relevant groups: disease-transmitting insects, endoparasites and ectoparasites; disease-irrelevant groups: adult insects and insect larvae), as independent variable and the scores on the ratings (fear, disgust and danger) as dependent variables. Separate ANOVAs for each rating scale and pairwise post hoc Tukey tests were performed to compare the animal groups and gender differences for each rating.

Correlations between ratings and participants' behaviour were performed using multiple regression (forward stepwise method). The mean PAQ score was controlled for the effect of keeping animals at home (by performing residual analysis), to avoid potential differences in fear of animals between animal owners and animal non-owners (Prokop et al. 2009; Prokop and Tunnicliffe 2010).

Results

Ratings

Reliability of respondents' ratings were highly consistent (Cronbach's alpha=0.95). Mean ratings of fear, disgust and danger for all five animal groups are shown in Table 2. The multivariate ANOVA revealed that there was a significant main effect of animal group on each rating scale ($F(12,2640.8)=100.7$, $p<0.001$, eta squared=0.31). Univariate ANCOVA's for each rating scale confirmed differences between animal groups (fear, $F(4,1000)=166.99$, $p<0.001$; disgust, $F(4,1000)=315.00$, $p<0.001$; danger, $F(4,1000)=177.28$, $p<0.001$). Disgust score was consistently higher than ratings of fear and dangerousness (Table 1). Tukey post hoc tests revealed that ecto and endoparasite pictures were rated significantly higher than all other pictures on all three variables (Table 2). Disease-transmitting insects were rated similarly to insect larvae. Adult insects were rated as the least fearful, least disgusting and least dangerous.

Significance of gender

The level of fear, disgust and dangerousness differed between male and female participants with consistently higher scores among female participants (MANOVA, $F(15,185)=5.61$, $p<0.001$, eta squared=0.31). Univariate ANCOVA's revealed that all gender differences were significant at $p<0.05$ and less.

The association between human behaviour and ratings of fear, disgust and danger

Multiple regression (forward stepwise method) with mean PAQ score as dependent variable and mean scores of fear and disgust and perceived danger of disease-relevant groups of invertebrates and disease-irrelevant adult insects and gender as independent variables was performed. In order to reduce large number of variables, the score of ecto and endoparasites was pooled because these two categories of invertebrates were perceived very similarly (Table 2). Score of disease-transmitting insects and insect larvae/earthworm was also pooled due to the same reason.

Table 2 Ratings of fear, disgust and estimated dangerousness for disease-relevant groups of animals (disease-transmitting insects, endoparasites and ectoparasites) and disease-irrelevant groups (adult insects and insect larvae)

	Fear		Disgust		Danger		*n*
Animal group	Mean	SE	Mean	SE	Mean	SE	
Disease-relevant insects	2.45[b]	0.06	3.73[b]	0.05	2.53[b]	0.04	201
Endoparasites	3.52[a]	0.06	4.29[a]	0.05	3.58[a]	0.04	201
Ectoparasites	3.36[a]	0.06	4.37[a]	0.05	3.38[a]	0.04	201
Adult disease-irrelevant insects	1.73[c]	0.06	2.19[c]	0.05	1.80[c]	0.04	201
Insect larvae/earthworm	2.58[b]	0.06	3.86[b]	0.05	2.59[b]	0.04	201

Letters (a–c) denote significant differences based on Tukey post hoc test. Identical letters mean that the difference between means is not statistically significant. Different letters mean that differences between means are significant ($p<0.001$)

The model was significant ($R^2=0.16$, $F(6,194)=6.02$, $P<0.001$).The mean scores of disgust of disease-irrelevant insects and fear of ecto and endoparasites were strongest predictors of parasite avoidance score (Table 3). Disgust of disease-relevant insects or insect larvae/earthworm correlated with parasite avoidance score in the same manner. This means that fearful participants or participants who rated insects as more disgusting tend to avoid caressing dogs and cats, are less willing to help the homeless and wash their hands more frequently than less fearful participants. Unexpectedly, participants who rated ecto and endoparasites as more disgusting and participants with higher fear of disease-relevant insects or insect larvae performed fewer anti-parasite behaviours than others. Some variables were removed from the model (Table 3).

Discussion

This study was focused on the evolutionary explanation of human disgust, fear and danger of disease-relevant invertebrates. We found that there is a substantial difference in the subjective response to various invertebrate groups: ecto and endoparasites were rated highest in fear, disgust and danger, followed by disease-relevant insects and insect larvae/earthworms and disease-irrelevant adult insects. Fear, disgust and danger were lowest for the latter group of invertebrates. The responses to arthropods that possess health risk are indeed different from disease-irrelevant groups which suggest that there is no general aversion against arthropods. These results support current findings of Gerdes et al. (2009) who found that wasps or spiders, that can cause significant medical problems (Camazine 1988; Vetter and Visscher 1998), were rated by participants in Germany as more disgusting and dangerous than butterflies most probably because latter group of invertebrates is much less dangerous to humans than the former group. These authors similarly conclude that aversion against arthropods is not identical, but each group of animals is perceived differently. Thus, the application of the biological preparedness hypothesis (Seligman 1971) seems to be a powerful explanation of the nature of different perception of various invertebrate groups.

Because invertebrates associated with serious health risks were perceived most negatively, it is possible that aversion toward these groups of animals is naturally selected for and humans therefore attempt to avoid them. Why, however, were disease-relevant insects not perceived identically to ecto and endoparasites? One possible explanation lies in the real risk of being infected by disease-relevant insects in Slovakia (central Europe). Unlike tropical regions, where mosquitoes are known to transmit malaria (Sachs and Malaney 2002) lymphatic filariasis (Chernin 1977) and other infectious diseases, no similar diseases occur in Slovakia. This may be the reason why disease-relevant insects like mosquitoes did not receive a

Table 3 Linear multiple regression (forward stepwise method) on Parasite Avoidance Questionnaire (PAQ) score

	β	*t*(194)	*P*
Intercept		−0.45	0.65
Disgust of disease-irrelevant insects	0.32	3.26	<0.001
Fear of ecto and endoparasites	0.48	3.82	<0.001
Danger of disease-irrelevant insects	−0.15	−1.39	0.17
Disgust of ecto and endoparasites	−0.32	−3.11	<0.001
Fear of disease-relevant insects and insect larvae/earthworm	−0.29	−2.21	0.03
Disgust of disease-relevant insects and insect larvae/earthworm	0.24	2.14	0.03

Gender, danger of disease-relevant insects/earthworm, danger of ecto and endoparasites and fear of disease-irrelevant insects predictors were excluded from the model high score. Current research supports this idea, because (Prokop et al. 2010) it was found that people living in areas with high parasite prevalence rate invertebrates as more disgusting and dangerous than peoples from areas with low parasite prevalence. We do not reject the fact that disgust and fear of disease-relevant animals is universal across cultures (Davey et al. 1998; Curtis et al. 2004). However, we suggest that natural selection favouring animal avoidance is stronger in regions where cost of contact with risky animals is higher.

A similar question, as to why insect larvae or earthworms were scored as highly as disease-relevant insect arises. Insect larvae and earthworms examined here are harmless to health but may be avoided because they are long, wriggly and/or slimy and resemble intestinal helminths (Curtis and Biran 2001). To support this view, *Tenebrio* larvae that resemble endoparasitic worms the most, compared with other four species, scored highest for disgust (data not presented in "Results"). Another explanation may be that worms are often associated with corpses that are also considered disgusting (Rozin et al. 2000). The latter explanation seems to be more probable, because most intestinal helminths do not infect humans during their adult stage, but rather as eggs. Thus, insect larvae are avoided because eating food that contains worms (e.g. blowflies in meat) might be fatal due to botulinum toxin produced by bacteria. Disgust against all kinds of worms seems to be therefore adaptive.

Higher rating scores in females have also been found in previous studies (Curtis et al. 2004). In agreement with these authors, we suggest that gender differences can be explained by higher investments of females in protecting the next generation (Fessler and Navarette 2003).

Human behaviour plays a crucial role in parasite transmission (Macpherson 2005). If we expect that costs associated with parasite transmission selectively influenced human behaviour, relationship between disgust, fear or self-perceived danger and anti-parasite behaviour should exist. We found several associations that generally corroborate an idea that heightened propensity to disgust or fear is associated with anti-parasite behaviour (Porzig-Drummond et al. 2009). For example, the mean scores of disgust of disease-irrelevant as well as disease-relevant insects or insect larvae and fear of ecto and endoparasites were significantly correlated with parasite avoidance score. Some unexpected correlations can be explained by low abilities to distinguish between endoparasitic worms and insect larvae as described above. Significant correlation between disease-irrelevant insects and parasite avoidance suggests that the behavioural immune system does not react to specific cues triggered by parasites, because these may greatly vary; instead it responds in a hypersensitive and over general way to the perceived presence of parasites in the sensory environment (Schaller 2006; Schaller and Duncan 2007). This is probably because benefits of hypersensitiveness outweigh cost. Unfortunately, the PAQ did not contain hand washing after defecation, which is related to diarrhoea caused by protozoan like *Giardia* or *Cryptosporidium* (Thompson 2000). Further validation and extension of PAQ is therefore needed.

Our data shows that harmful invertebrates, especially ecto and endoparasites, are rated significantly higher than animals that pose lower or no health risk. Furthermore, there were also significant associations between disgust, fear and danger, and specific behaviours directed to parasite avoidance. We conclude that disgust, fear and self-perceived danger were shaped by natural selection supporting the biological preparedness hypothesis (Seligman 1971). Further research in order to assess origin of animal fear and disgust should be focused especially on cross-cultural comparisons (for example, human perception of vectors of malaria and filiaria in tropical zones) and individual differences in perception of animals.

Acknowledgement We would like to thank John Young for improving the English of the manuscript. Three anonymous reviewers provided insightful comments on earlier drafts of this paper.

Appendix A

List of species used in Power-point presentation

Disease-relevant adult insects: *Aedes aegypti*, *Calliphora vomitoria*, *Eristalis tenax*, *Blatella germanica*, *Sarcophaga haemorrhoidalis*

Endoparasites: *Ascaris lumbricoides*, *Dracunculus medinensis*, *Taenia saginata*, *Enterobius vermicularis*, *Fasciola hepatica*

Ectoparasites: *Cimex lecturarius*, *Ixodes ricinus*, *Pediculus humanus*, *Hirudo medicinalis*, *Pulex irritans*

Disease-irrelevant adult insects: *Oryctes nasicornis*, *Coenagrion puella*, *Coccinella septempunctata*, *Chorthippus biguttulus*, *Papilio machaon*

Insect larvae/earthworm: *Culex* sp., *Chloroclystis rectangulata*, *Lumbricus terrestris*, *Tenebrio molitor*, *Coccinella septempunctata*

References

Bjerke T, Østdahl T, Kleiven J (2003) Attitudes and activities related to urban wildlife: pet owners and non-owners. Anthrozoös 16:252–262

Bonilla DL, Kabeya H, Henn J, Kramer VL, Kosoy MY (2009) Bartonella quintana in body lice and head lice from homeless persons, San Francisco, California, USA. Em Inf Dis 15:912–915

Brouqui P, Raoult D (2006) Arthropod-borne diseases in homeless. Century of rickettsiology: emerging, reemerging rickettsioses, molecular diagnostics, and emerging veterninary rickettsioses. Ann New Yord Acad Sci 1078:223–235

Brundage SC, Fitzpatrick AN (2006) Hepatitis A. Am Fam Phys 73:2162–2168

Camazine S (1988) Hymenopteran stings: reactions, mechanisms and medical treatment. Bull Entomol Soc Amer 34:17–21

Chernin E (1977) Patrick Manson (1844–1922) and the transmission of filariasis. Am J Trop Med Hyg 26:1065–1070

Crompton DWT (1999) How much human helminthiasis is there in the world? J Parasitol 85:397–403

Curtis V, Biran A (2001) Dirt, disgust, and disease: is hygiene in our genes? Persp Biol Med 44:17–31

Curtis V, Cairncross S (2003) Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. Lancet Inf Dis 3:275–281

Curtis V, Aunger R, Rabie T (2004) Evidence that disgust evolved to protect from risk of disease. Biol Lett 272:S131–S133

Davey GCL, McDonald AS, Hirisave U, Prabhu GG, Iwawaki S, Jim CI, Merckelbach H, de Jong PJ, Lejny PWL, Reimann L (1998) A cross-national study of animal fears. Behav Res Ther 36:735–750

Dorny P, Praet N, Deckers N, Gabriel S (2009) Emerging food-borne parasites. Vet Parasitol 163:SI 196–SI 206

Dubey JP (2009) Toxoplasmosis in pigs—the last 20 years. Vet Parasitol 164:89–103

Dubey JP, Jones JL (2008) *Toxoplasma gondii* infection in humans and animals in the United States. Int J Parasitol 38:1257–1278

Fan PC, Chung WC, Soh CT, Kosamaln ML (1992) Eating habits of East-Asian people and transmission of taeniasis. Acta Trop 50:305–315

Fessler D, Navarette C (2003) Domain specific variation in disgust sensitivity across the menstrual cycle: evidence in favour of an evolutionary account of sexual disgust. Evol Hum Behav 24:406–417

Duncan LA, Schaller M (2009) Prejudicial attitudes toward older adults may be exaggerated when people feel vulnerable to infectious disease: evidence and implications. Anal Soc Iss Pub Pol 9:97–115

Faulkner J, Schaller M, Park JH, Duncan LA (2004) Evolved disease-avoidance processes and contemporary xenophobic attitudes. Group Proc Intergr Behav 7:333–353

Gerdes ABM, Uhl G, Alpers GW (2009) Spiders are special: fear and disgust evoked by pictures of arthropods. Evol Hum Behav 30:66–73

Goetz AT, Shackelford TK (2009) Sexual coercion in intimate relationships: a comparative analysis of the effect of women's infidelity and men's dominance and control. Arch Sex Behav 38:226–234

Gonçalves MLC, Araújo A, Ferreira LF (2003) Human intestinal parasites in the past: new findings and a review. Mem Inst Oswaldo Cruz 98:103–118

Hwang SW, Kiss A, Ho MM, Leung CS, Gundlapalli AV (2008) Infectious disease exposures and contact tracing in homeless shelters. J Health Care Poor Underserved 19:1163–1167

Lindgren E, Jaenson TGT (2006) Lyme borreliosis in Europe: influences of climate and climate change, epidemiology, ecology and adaptation measures. EUR/04/5046250, Denmark, p. 34

Macpherson CNL (2005) Human behaviour and the epidemiology of parasitic zoonoses. Int J Parasitol 35:1319–1331

Nunnaly J (1978) Psychometric theory. McGraw-Hill, New York

Öhman A, Carlsson K, Lundqvist D, Ingvar D (2007) On the unconscious subcortical origin of human fear. Phys Behav 92:180–185

Palmer CS, Traub RJ, Robertson ID, Devlin G, Rees R, Thompson RCA (2008) Determining the zoonotic significance of *Giardia* and *Cryptosporidium* in Australian dogs and cats. Veter Parasitol 154:142–147

Park JH, Faulkner J, Schaller M (2003) Evolved disease-avoidance processes and contemporary anti-social behavior: Prejudicial attitudes and avoidance of people with physical disabilities. J Nonv Behav 27:65–87

Phillips ML, Young AW, Senior C, Brammer M, Andrew C, Calder AJ, Bullmore ET, Perrett DI, Rowland D, Williams SCR, Gray JA, David AS (1997) A specific neural substrate for perceiving facial expressions of disgust. Nature 389:495–498

Phillips ML, Senior C, Fahy T, David AS (1998) Disgust: the forgotten emotion of psychiatry. Br J Psychiatry 172:373–375

Porzig-Drummond R, Stevenson R, Case T, Oaten M (2009) Can the emotion of disgust be harnessed to promote hand hygiene? experimental and field-based tests. Soc Sci Med 68:1006–1012

Prokop P, Özel M, Uşak M (2009) Cross-cultural comparison of student attitudes toward snakes. Soc Anim 17:224–240

Prokop P, Tunnicliffe SD (2010) Effects of having pets at home on children's attitudes toward popular and unpopular animals. Anthrozoös 23:21–34

Prokop P, Usak M, Fančovičová J (2010) Health and the avoidance of macroparasites: a preliminary cross-cultural study. J Ethol doi:10.1007/s10164-009-0195-3

Rabie T, Curtis V (2006) Handwashing and risk of respiratory infections: a quantitative systematic review. Trop Med Int Health 11:258–267

Ramirez NE, Ward LA, Sreevatsan S (2004) A review of the biology and epidemiology of cryptosporidiosis in humans and animals. Microb Infect 6:773–785

Reeves WK, Murray KO, Meyer TE, Bull LM, Pascua RF, Holmes KC, Loftis AD (2008) Serological evidence of typhus group rickettsia in a homeless population in Houston, Texas. J Vect Ecol 33:205–207

Rozin P, Haidt J, McCauley C (2000) Disgust. In: Lewis M, Haviland JM (eds) Handbook of emotions, 2nd edn. Guilford, New York, pp 637–653

Rubio-Godoy M, Aunger R, Curtis V (2007) Serotonin—a link between disgust and immunity? Med Hyp 68:61–66

Sachs J, Malaney P (2002) The economic and social burden of malaria. Nature 415:680–685

Schaller M (2006) Parasites, behavioral defenses, and the social psychological mechanisms through which cultures are evoked. Psychol Inq 17:96–101

Schaller M, Duncan LA (2007) The behavioral immune system: its evolution and social psychological implications. In: Forgas JP, Haselton MG, von Hippel W (eds) Evolution and the social mind. Psychology, New York, pp 293–307

Schmidt GD, Roberts LS (1989) Foundations of Parasitology, 4th edn. St. Louis, Mosby College

Seligman MEP (1971) Phobias and preparedness. Behav Ther 2:307–320

Smith JL (1994) Taenia solium—neurocysticercosis. J Food Prot 57:831–844

Thompson RCA (2000) Giardiasis as a re-emerging infectious disease and its zoonotic potential. Int J Parasitol 30:1259–1267

Vetter RS, Visscher PK (1998) Bites and stings of medically important venomous arthropods. Int J Dermatol 37:481–496

Warren K, Bundy D, Anderson R, Davis AR, Henderson DA, Jamison DT, Prescott N, Senf A (1991) Helminth infection. In: Jamieson D, Mosley W (eds) Evolving health sector priorities in developing countries. World Bank, Washington