Parasites enhance self-grooming behaviour and information retention in humans

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ABSTRACT

Self-grooming is a common behavioural strategy used by various animals to reduce parasite loads. We experimentally tested the adaptive significance of self-grooming model in a sample of Slovak participants. Propensity to self-grooming was activated by visual presence of parasites with verbal information about health risks caused by parasites suggesting that the programmed grooming model works in humans. People who think of themselves as more vulnerable to disease transmission reported higher frequency of self-grooming suggesting that there is a link between the immune system and parasite avoidance behaviour. Considering that the emotion of disgust plays a role in activation of parasite avoidance behaviour, we suggested that knowledge of disgusting stimuli (parasites) would be better retained than knowledge of non-disgusting (hormones), and, thus, non-life-threatening stimuli. As expected, knowledge on parasites tested immediately after the experiment was significantly better than knowledge on hormones suggesting that survival-relevant information is better retained than survival-irrelevant data. However, scores on memory tests did not seem to be influenced by the individual's immune system. Overall, this study showed that self-grooming in humans is functional when disease threat is salient. Human memory systems are tuned to information relevant to survival providing further evidence that human cognition is shaped by natural selection.

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1. Introduction

Survival and reproduction largely depends on an individual's ability to combat with disease-causing parasites. Parasites are therefore considered to be strong evolutionary forces influencing the evolution of human physiology and behaviour (Schaller and Duncan, 2007; Wolfe et al., 2007; Prokop and Fedor, 2013). While physiological mechanisms that eliminate disease threat are activated in the second line of individual's defence against disease (the biological immune system, BIS; Parham, 2009; Schaller et al., 2010), the first line of defence comprises a set of cognitive, emotional and behavioural mechanisms which allows individuals to detect the potential presence of parasites in objects (or individuals) and act to prevent contact with them (the behavioural immune system, BEH; Schaller, 2006; Schaller and Duncan, 2007; Neuberg et al., 2011).

Both physiological and behavioural mechanisms interact with each other suggesting that the activation of one of these systems may trigger activation of the other system (Schaller et al., 2010; Miller and Maner, 2011).

Grooming is a common behavioural strategy used by animals in an effort to reduce transmission of ectoparasites (Hart, 1990, 1994; Moore, 2002). Grooming is documented also in parasite-free environments (Hart et al., 1992; Mooring and Hart, 1997; Mooring et al., 2006) suggesting that it has an endogenous component (Moore, 2002; Mooring et al., 2004). Two non-mutually exclusive models (Mooring and Samuel, 1998) are used to explain neuro-physiological regulation of grooming. The "programmed grooming" model postulates an existence of central programming (ultradian clock or endogenous generator) that periodically activates a bout of grooming in order to remove ectoparasites before they are able to attach/bloodfeed (Hart et al., 1992; Mooring et al., 2004, 2006; Hawlena et al., 2008). This model assumes that a host invests in antiparasitic grooming on a regular basis irrespective on the presence of parasites in the environment (Hart, 1997; Mooring et al., 2006) and that the frequency of grooming may be modulated by some cues that are associated with increased vulnerability

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to ectoparasite infestation (Hart, 1997; Hawlena et al., 2008). The "stimulus driven" model postulates a peripheral mechanism that is a direct response to cutaneous irritation caused by sucking by ectoparasites (Willadsen, 1980; Wikel, 1984; Hawlena et al., 2008). According to this model, a host is not expected to invest in grooming in absence of a relevant stimulus (Wakelin, 1996). Similar to other primates (Hart, 1990; Dunbar, 2012), humans also groom themselves (Thompson, 2010), but whether the programmed grooming model is applicable to our species is not yet clear. Considering the ectoparasite reduction function of grooming, it is assumed that individuals who think of themselves as more vulnerable to infectious diseases groom themselves more than individuals who perceive themselves as less vulnerable to infectious diseases (Thompson, 2010).

According to evolutionary views, human memory may have evolved to solve adaptive problems relevant to fitness (adaptive memory; Nairne et al., 2007; Nairne and Pandeirada, 2010). Research shows that words relevant to survival (Nairne et al., 2008; Kang et al., 2008), dangerousness of animals (Barrett and Broesch, 2012), poisonousness of plants (Prokop and Fančovičová, 2014) and life-threatening situations (Pynoos and Nader, 1989) are better retained than fitness irrelevant information. Furthermore, our memory processes seem to be positively influenced by the emotion of disgust, because disgusting stimuli are retained better than neutral-looking stimuli (Charash and McKay, 2002; Silva et al., 2012). Given that the emotion of disgust evolved as disease-avoidance mechanism in humans (Curtis et al., 2004; Oaten et al., 2009; Tybur et al., 2013), the association between adaptive memory and disgust-evoking stimuli is reasonable.

In this study we aimed to investigate (i) whether the programmed grooming model is applicable to humans, (ii) whether human memory preferentially retains information about disgusting and disease-relevant stimuli compared with non-disgusting and disease-irrelevant stimuli, and, finally, (iii) whether the BIS activates cognitive processes that facilitate action and the detection of parasites (BEH). Specifically, we hypothesized that (1) self-grooming would be induced by visual contact and information about parasites (activation of BEH) and that (2) self-grooming would be positively correlated with the self-perceived vulnerability to diseases to test the existence and functionality of the programmed grooming model. Furthermore, we hypothesized that (3) Information about parasites, as explicit examples of disease carriers, would be better retained than information on non-disease carriers to test the adaptive memory theory in humans. Finally, we expect that (4) People who think of themselves as more vulnerable to infectious diseases will retain more information on parasites than less disease vulnerable people in order to test the activation of BEH by the biological immune system (BIS).

2. Methods

2.1. Participants

A total of 95 Slovak students with mean age 30.11 (SD = 8.52) years (range = 19–47 years) attending Trnava University participated in the study. An additional 24 students were not included, because they were not present in the both sessions (see below). The mean age of the university students was higher than a typical undergraduate sample because these students at the campus where the study was conducted differ from traditional students, such as being employed full-time and/or having children. This yielded a more diverse sample of participants along several demographic variables compared with studies that include only full-time university students. Due to a strong female-bias in educational faculties in Slovakia, only four students were men. We therefore decided

to not compare possible gender differences. Removing men from a sample did not change results of the statistical analyses. All participants received an extra credit from a Human biology course for their participation on the research.

2.2. Research instruments

2.2.1. Perceived vulnerability to disease scale (PVDS)

The PVDS (Duncan et al., 2009) was used to assess the participants' self-perceived vulnerability to disease. This scale consists of 15 items; one subscale assesses beliefs about one's own susceptibility to infectious diseases (perceived infectability [PVD-PI]; 7 items with $\alpha = 0.83$); the second subscale assesses emotional discomfort in contexts that suggest an especially high potential for pathogen transmission (germ aversion [PVD-GA]; 8 items with $\alpha = 0.64$). Items were rated on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Negatively worded items were scored in reverse order. An additional item that precisely estimate the number of infectious diseases in past year (How many times were you contaminated by infectious disease [e.g. cold, influenza, etc.] during the last year?) modified according to Prokop et al. (2010a,b,c) was used to examine actual vulnerability to infectious diseases.

2.2.2. Pathogen disgust scale (PDS)

The PDS ($\alpha = 0.7$) scale was adopted from Tybur et al. (2009). This scale is designed to measure disgust elicitors caused by sources of various pathogens (e.g., stepping on dog poop). Participants responded to items on a five-point Likert scale from not at all disgusting (1) to extremely disgusting (5).

2.2.3. Human parasite avoidance scale (HPAS)

The HPAS is a self-constructed, three-item scale designed to measure propensity to self-grooming in humans. Our restriction to *propensity* rather than normal self-grooming was made because social norms may inhibit these behaviours during educational process where the research was carried out. Thus, participants were expected to partially or completely supress self-grooming or other forms of hygiene. Known similar scales (e.g., Prokop and Fančovičová, 2010, 2011) do not contain grooming behaviour (except for washing hands) and could not be therefore used. The items were: how many times during the last 45 min did you feel a need *to scramble yourself*?, How many times during the last 45 min did you have a feeling that something is *crawling on your body*? (responses for both items were 1 = 0 times, 2 = 1–3 times, 3 = 4–5 times, 4 = 6–7 times, 5 = 8 times and more). The final item was how much do you feel a need to *actually wash your hands*? (1 = absolutely not, 5 = extremely much) modified after Prokop and Fančovičová (2011). Reliability of the HPAS was established before and after the treatment (see Section 3).

2.3. Procedure

The research was carried out in two sessions with two separate groups of students. The first part of the experiment was conducted in November 2013 (session 1) with two groups of students. The second part of the experiment with the same two groups of students was conducted in December 2013 (session 2). Both sessions were realized on the same time of day (one group in the morning, second group in the afternoon on session 1 and the same on session 2). On session 1, all students received the PVDS and PD questionnaires. Then the experimenter (PP) lectured an oral presentation about the skeletal and circulatory system (45 min each with one 10 min break). After the presentation the HPAS was administered to students. On session 2, students received oral presentations from the same experimenter about hormones and about

common human parasites (45 min each). The length of presentations was standardized to 17 parasites and 17 hormones, similar visualization and the same number of PPT slides. The presentation concerning parasites comprised frequent human parasites such as tapeworms (*Taenia* spp.), intestinal roundworms (*Ascaris lumbricoides*), pinworms (*Enterobious vermicularis*) and others. The presentation concerning hormones was focused on products of major human endocrine glands such as the hypophysis, thyroid gland, pancreas and others. In all cases, basic information on the position of a parasite/endocrine gland and their effects on the human body (including hypo/hyperfunction of endocrine glands and low/high parasite loads) were presented. In one group the presentation about hormones was preceded by the presentation of parasites and vice versa (*n* = 40 and 55 students per group). After the presentation about parasites, both groups received the HPAS. After both presentations, a 20 multiple choice surprise memory self-constructed test with 10 questions about parasites and 10 questions about hormones was administered. Each question was presented on PPT presentation, read by the experimenter and the response time was standard for all questions (30 s). Questions on hormones and parasites were mixed and presented in a random order. The experiment was not anonymous, because pair-wise comparisons were required. The order of presentation (hormones presented first or parasites presented first) did not result in significant differences in dependent variables between the two groups of participants, thus results from both groups were pooled in order to increase the power of statistical tests. After the experiment, all the participants were debriefed and the research goals were explained.

2.4. Statistical analyses

Mean scores of domains described above were used in statistical tests. Comparison of mean scores of the same participants in session 1 and 2 was made by paired *t*-tests. Associations between HPAS and other domains were calculated by multiple regression (forward stepwise method) in order to select the most parsimonious model. Next, we conducted a median split on PVDS (total scale) to dichotomize our sample into less vulnerable (*n* = 45) and restricted (*n* = 50) categories. These categories were compared with *t*-test for independent samples. Simple correlations were calculated with Pearson *r*. The effect size measure (Cohen's *d*) for groups was calculated according to Cohen (1988), who offered the following guidelines for interpreting effect sizes: *d* = 0.20 (small effect), *d* = 0.50 (medium effect), and *d* = 0.80 (large effect). All statistical tests were performed with Statistica (v8, StatSoft 2007, Tulsa, OK, U.S.A., http://www.statsoft.com).

3. Results

3.1. Hypothesis 1: self-grooming behaviour will be induced by visual contact and information about parasites

The HPAS-*before* (α = 0.34) had much lower reliability than HPAS-*after* the treatment (α = 0.79), suggesting that the treatment consistently activated self-grooming behaviour. As predicted, the mean score of the HPAS (human parasite avoidance scale) was significantly higher after the treatment (paired *t*-test, *t* = 7.01, df = 94, *p* < 0.0001, *d* = 0.79, Fig. 1).

3.2. Hypothesis 2: self-grooming behaviour will be positively correlated with the self-perceived vulnerability to diseases

The mean score of the HPAS obtained *before* the treatment served as the dependent variable and the PDS (pathogen disgust scale), PVD-PI, PVD-GA, age and number of infectious diseases in the
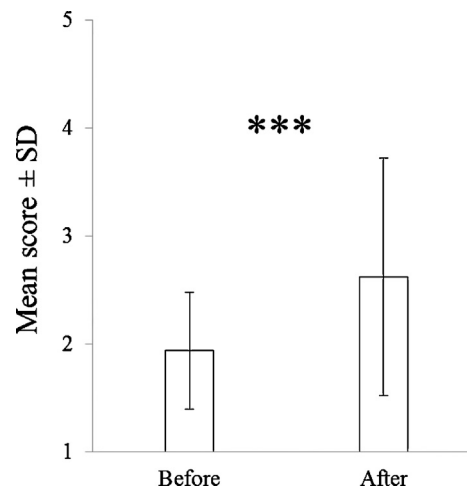

Fig. 1. Differences in the human arasite avoidance scale (HPAS) before and after the presentation about parasites.

last year were continuous predictors in the forward stepwise multiple regression. The model was significant (R^2 = 0.09, *F*(2,92) = 4.4, *p* = 0.015) and two variables were retained in the model: the number of infectious diseases in the last year and the PVD-GA subscale (β = 0.22 and 0.18, *p* = 0.03 and 0.06, respectively). When the HPAS score obtained *after* the treatment was defined as dependent variable, the model was, again, statistically significant (R^2 = 0.11, *F*(2,92) = 5.69, *p* = 0.005). The same variables entered the model (the number of infectious diseases in the past year and the PVD-GA subscale, β = 0.25 and 0.21, *p* = 0.01 and 0.04, respectively). Additional analysis in which participants were divided according to their perceived vulnerability to disease (median split from PDVS total score) showed that there were no differences in the mean HPAS between more (mean ± SD, 2.13 ± 0.5, *n* = 50) and less disease vulnerable people (1.98 ± 0.45, *n* = 45) before treatment (*t*-test, *t* = 1.55, df = 93, *p* = 0.12, *d* = 0.31). More disease vulnerable people, however, scored significantly higher on HPAS scale after the treatment (2.74 ± 0.91, *n* = 50) compared with their less disease vulnerable counterparts (2.38 ± 2.74, *n* = 45) (*t* = 2.07, df = 93, *p* = 0.04, *d* = 0.43). Collectively, these results support the hypothesis that anti-parasite behaviour positively correlates with vulnerability to diseases.

3.3. Hypothesis 3: information on parasites will be better retained than information on hormones

The mean parasite knowledge score was significantly higher than the mean hormone knowledge score supporting Hypothesis 3 (paired *t*-test, *t* = 16.27, df = 94, *p* < 0.0001, *d* = 2.02, Fig. 2).

3.4. Hypothesis 4: people more vulnerable to diseases will retain more information on parasites than less disease vulnerable people

Correlation between parasite knowledge score and PVD-PI, PVD-GA and with the number of infectious diseases in the last year was not significant (Pearson *r* = 0.02, 0.06 and −0.03, all *p* > 0.54, respectively) providing no support for the Hypothesis 4. Other additional correlations with the PDS, or with HPAS-*before* or *after* were also not significant (*r*s = 0.07–0.08, all *p* > 0.43). Correlations with the hormone knowledge score were also non-significant (*r*s = −0.07 to 0.16, all *p* > 0.12) as well as correlations with PDS, or with HPAS-*before* or *after* (*r*s = −0.04 to 0.05, all *p* > 0.58). A difference score between parasite and hormone knowledge did not correlate with any of the above mentioned variables (*r*s = −0.09 to 0.068, all *p* > 0.36).
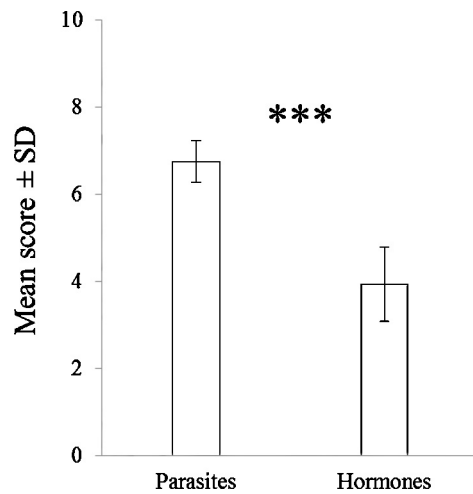
Fig. 2. Differences in the parasites knowledge score and the hormones knowledge.

4. Discussion

This study investigated the functional significance of self-grooming, a widespread strategy that animals use to reduce parasite load (e.g., Hart, 1990; Moore, 2002; Prokop and Fedor, 2013) in humans. In particular, we were interested in whether an endogenously programmed behaviour, activated preventively in order to remove ectoparasites before they are able to attach/bloodfeed (Hart et al., 1992; Mooring et al., 2004, 2006), can be applied to our species. As far as we are aware, this is the first attempt to examine programmed grooming in humans.

Visual cues of parasite threat along with verbal information on health risks caused by parasites resulted to activation of self-grooming propensity. The propensity to self-groom was significantly lower when no cues of parasite threat were present (session 1) suggesting that it responds specifically to disease threat. This supports the idea that self-grooming is partly triggered by both exogenous stimuli (the stimulus driven model), but also by endogenous processes (the programmed grooming model), because only visual cues of parasites without skin irritation caused by ectoparasites activated self-grooming in humans. This is in agreement with the idea that both central control and stimulus-driven mechanisms operates concurrently and are not mutually exclusive (Mooring and Samuel, 1998). Perhaps due to some costs of grooming (e.g., vigilance for predators, Hart, 1990), endogenous responses to specific cues, rather than superficial ones, are favoured by natural selection.

Self-perceived vulnerability to infectious diseases (number of infectious diseases in last year) and emotional discomfort when cues of disease are salient (PVD-GA subscale) were positively associated with self-grooming propensity. This result is fully in agreement with Thomson (2010) and suggests that humans who consider themselves to be at high risk of disease groom themselves more to maintain health, and preventively reduce ectoparasitic load. Considering that some ectoparasites, such as fleas that transmit plague, killed 25% and 50% of the populations of Europe, Asia and Africa in Mediaeval History (Gottfried, 1983), increased investment to self-grooming may be beneficial especially for immunologically compromised individuals.

The next goal of this study was to examine the idea that memory is shaped by natural selection and, therefore, remembering is selective and information relevant to survival are better retained than survival-irrelevant information (Nairne et al., 2007; Nairne and Pandeirada, 2010). The surprise memory test applied after the treatment yielded highly significant differences favouring better information retention about parasites compared with hormones. This fits with the concept of adaptive memory (e.g., Nairne et al., 2007; Barrett and Broesch, 2012; Prokop and Fančovičová, 2014). Compared with parasites, information about hormones can hardly help us to avoid infectious diseases and, ultimately, improve survival. However, knowledge about parasites may be useful immediately or in near future and may reduce mortality or morbidity in human populations (Curtis and Cairncross, 2003). Finally, the disgusting nature of parasites (Prokop et al., 2010a,b,c) could enhance information retention (Charash and McKay, 2002; Silva et al., 2012), which could contribute to better knowledge about parasites. Collectively, these results contribute to further understanding about the functioning of adaptive memory in humans.

The final goal of this study was to investigate the associations between BIS and BEH. Some studies showed that BEH may activate BIS, because visual cues depicting infectious disease heightened immunological response (Schaller et al., 2010). Other work showed that BEH was activated by BIS, because immunologically compromised participants were more sensitive to cues associated with disease (Miller and Maner, 2011). Our study did not find any evidence that participants with high perceived vulnerability to diseases or with heightened self-grooming propensity had superior cognitive abilities in terms of retention of survival-relevant information. However, the association between BIS and BEH was confirmed by correlations with vulnerability to diseases and self-grooming propensity described above, suggesting that there is a link between immune system and *behaviour* in humans (Miller and Maner, 2011). The failure of establishing correlations between BIS and *cognitive* abilities needs further research. Perhaps the superior effect of information retention about parasites can appear later, in long-term memory tests. Importantly, the BIS was investigated only through subjective ratings of vulnerability to diseases. Further research is required to establish whether the self-perceived vulnerability to diseases correlates with the immune system.

To conclude, the programmed grooming model can be applied on humans, because no direct bloodfeeding on the skin is necessary for activation of self-grooming. Self-grooming was, however, specifically activated in visual presence of parasites, suggesting that both programmed grooming and stimulus driven model operates concurrently. Visual cues of disease threat also enhance information retention suggesting that parasites trigger a set of cognitive and behavioural mechanisms that can enhances survival.

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