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COVID-19 vaccination and the behavioral immune system: The newcomer and the old friend get along in preventing infection

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ABSTRACT

Despite its old evolutionary history and emotional relevance, the behavioral immune system is one of the less studied individual predictors of vaccine uptake. To fill the gap, we conducted a large online study (2072 participants) during the spring 2022 when the great majority of the Italian population had already received at least one dose of the COVID-19 vaccine. Hierarchical binary logistic regression showed that, after controlling for the confounding effects of demographic and personality factors, there was a significant and positive association between pathogen disgust sensitivity and COVID-19 vaccine uptake (OR, 1.68; 95% CI, 1.42–1.99). The likelihood of being vaccinated for a participant with the highest possible score on the PVD Germ Aversion scale was approximately 12 times higher than the likelihood for a participant with the lowest possible score. Public health messaging could leverage the activation of the behavioral immune system as an emotional driver of vaccine uptake.

1. Introduction

The COVID-19 pandemic prompted a rapid international search for safe and effective vaccines against the SARS-CoV-2 virus. As of January 24, 2022, 33 approved vaccines were in use in 197 countries, with 10 vaccines approved for emergency use by World Health Organization (Young et al., 2022). To optimize the operational implementation of mass vaccination policies, it is critical to consider not only the supply of vaccines but also the individual factors that facilitate or, on the contrary, hinder vaccine uptake.

Despite previous successful vaccines, the COVID-19 pandemic has been associated with a greater shift of attention to "vaccine hesitancy". Vaccine hesitancy, defined as a "delay in acceptance or refusal of vaccines despite availability of vaccination services" (World Health Organization, 2014) represents a significant barrier to the success of any vaccination program. Several factors contributing to vaccine hesitancy have been identified, with most concerns relating to fear of side effects, distrust in the vaccine, vaccine related risks and the perceived effectiveness of the vaccine (Burke et al., 2021). These findings are valuable in identifying populations to be targeted and psychological barriers that may need to be overcome in appeals to reduce vaccine hesitancy. However, it is also important to identify psychological factors that encourage vaccine uptake, which can be utilized to shape possible messaging campaigns and interventions to lower vaccine hesitancy and increase vaccination uptake (Wang et al., 2021; Shook et al., 2022).

In line with the ongoing research task of identifying individual predictors associated with vaccine acceptance, the aim of the present study was to ascertain which is the relationship between the activation of the behavioral immune system and COVID-19 vaccine uptake. The question is biologically relevant because it relates to the more general topic of how evolutionary old mechanisms interact with evolutionary novelties in impacting human health (Gluckman et al., 2019; Basile et al., 2021).

Schaller (2011) has convincingly demonstrated that selection pressures have reinforced our defenses against infections by causing the evolution of a behavioral immune system that is separate from, and complementary to, the physiological immune system. The behavioral immune system includes a set of proactive mechanisms that inhibit contact with pathogens in the first place. These mechanisms offer a sort of psychological and behavioral prophylaxis against infection (Schaller et al., 2015; Iwasa et al., 2021). The two emotional and interrelated reactions associated with the activation of the behavioral immune system are fear of infection and pathogen disgust sensitivity (Troisi, 2020; Troisi et al., 2022). The activation of the behavioral immune system is expected to depend on environmental conditions that reflect higher risk

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of contracting infectious disease. According to the calibration hypothesis (Schaller, 2011), ecologies associated with increased infection threat should cause a heightened sense of pathogen disgust sensitivity. Leveraging the COVID-19 pandemic, Boggs et al. (2022) have provided empirical support for the calibration hypothesis. They found that disgust sensitivity increased following the COVID-19 outbreak and that the degree of this increase was moderated by an individual's subjective concern about contracting the disease.

Despite its old evolutionary history and emotional relevance, the behavioral immune system is one of the less studied individual predictors of vaccine acceptance. To date, no study has explored the possible link between pathogen disgust sensitivity and the actual behavior (i.e., COVID-19 vaccine uptake) though three studies have assessed its association with a person's beliefs and attitudes towards vaccination (Kempthorne and Terrizzi, 2021; Karlsson et al., 2022; Solak et al., 2022). To fill the gap, we conducted a large online study (N = 2072) during the spring 2022 when the great majority of the Italian population had already received at least one dose of the COVID-19 vaccine.

2. Material and methods

2.1. Participants

The sample included 2072 participants (mean age ± SD: 38.00 ± 13.62 years; mean education ± SD: 15.33 ± 3.26 years) who completed the survey between March 1 and April 10, 2022. Table 1 provides a detailed overview of the demographics of our sample.

Data collection was made by implementing an anonymous online survey based on a customized Jotform questionnaire (https://www.jotform.com). The survey could be completed using a personal computer/laptop, tablets, or smartphone, in approximately 30 min. Participants identified themselves by providing an alphanumeric code or a nickname. The unique ID widget was used to prevent multiple compilation of the online questionnaire. Participants were recruited trough virtual snowball sampling. A small pool of initial informants nominated, through their real or virtual social networks, other participants who expressed their interest to contribute to the study. Eligibility criteria was minimum age of 18 years and residence in Italy.

To access the online questionnaire, participants were requested to sign an informed consent that explained the procedure of data collection and the aims of the study. No payment was given for participation. The study was approved by the Ethical Committee of the Department of Dynamic and Clinical Psychology, Sapienza, University of Rome (Prot. n. 0000453 and Prot. n. 0000112).

After electronically agreeing to be part of the study, participants completed the primary study measures and other questionnaires in a random order, except for demographics, COVID-19 infection status (Have you ever gotten a confirmed diagnosis of COVID-19?) and COVID-19 vaccination (Did you get the COVID-19 vaccine?) which appeared last (response options were Yes coded as 1 or No coded as 0).

Table 1
Descriptive data for the 2072 participants.

Gender	Frequency	Percentage
Men	399	19.26%
Women	1673	80.74%
Age		
18-29	780	37.64%
30-39	413	19.93%
40-59	720	34.74%
60 and over	159	7.67%
Education		
Primary school	87	4.20%
High school	928	44.79%
Graduate	919	44.35%
Post-graduate	138	6.66%
Covid infection		
Yes	822	39.68%
No	1250	60.32%
Covid vaccination		
Yes	1941	93.68%
No	131	6.32%

2.2. Measures

2.2.1. The ten item personality inventory (TIPI) scale

The TIPI is a short scale developed to measure personality traits according to the Big Five model (also known as the OCEAN model: Openness to experience, Conscientiousness, Extraversion, Agreeableness, Neuroticism) in working or clinical settings in which assessment time is limited (Gosling et al., 2003). The TIPI was developed using descriptors from other well-established Big Five instruments. Each of the ten items is rated on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). The version used in this study was the revised Italian version (I-TIPI-R) (Chiorri et al., 2015) which showed adequate factor structure, test-retest reliability, self-observer agreement and convergent and discriminative validity with the Big Five Inventory (BFI).

2.2.2. Disgust propensity and sensitivity scale-revised (DPSS-R)

Pathogen disgust sensitivity is elicited by specific stimuli and should be distinguished by general disgust propensity and sensitivity. For this reason, we included among the psychometric measures the Italian version of the DPSS-R (Martoni et al., 2017). The revised version of the DPSS (van Overveld et al., 2006) consists of 16 items aiming at assessing disgust propensity (e.g., "I find something disgusting"; "I worry that I might swallow a disgusting thing") and disgust sensitivity (e.g., "When I feel disgusted, I worry that I might pass out"; "I think feeling disgust is bad for me") irrespective of disgust elicitors. Each statement is rated on a 5-point Likert scale (from 1 "never" to 5 "always"). In our study, the DPSS-R total score showed good internal consistency (Cronbach's α 0.81).

2.2.3. The perceived vulnerability to disease (PVD) scale

To measure the activation of the behavioral immune system, we used the PVD scale. The PVD scale is a measure assessing participants perceived susceptibility to catching infectious disease and their aversion to pathogens (Duncan et al., 2009). The PVD consists of 15-items divided into two subscales. The Germ Aversion subscale (GA; 8 items) measures aversive response in relation to potential pathogen transmission (e.g., "I prefer to wash my hands pretty soon after shaking someone's hand"). The Perceived Infectability subscale (PI; 7 items) measures perceived susceptibility to infectious diseases in general (e.g., "I am more likely than the people around me to catch an infectious disease"). Germ Aversion predicts responses rooted in intuitive emotional appraisals of risk, whereas Perceived Infectability predicts responses informed by more rational cognitive appraisals. All ratings of items were made on a scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). A total score for each subscale was created by adding up each item score. Higher scores reflect greater germ aversion or perceived infectability. The version used in this study was the Italian version (Troisi et al., 2022). The internal consistency of the two subscales was adequate and acceptable in the present sample: Cronbach's α 0.82 for Perceived Susceptibility and 0.78 for Germ Aversion.

2.3. Statistical analysis

One-way Analysis of Variance (ANOVA) was used to compare vaccinated and unvaccinated participants on dimensional variables. Gender distribution across the two groups was calculated by using the chi-square statistic. Hierarchical binary logistic regression was used to identify the significant predictors of vaccination. Effects are reported as odds ratios (exp(β)) with 95% confidence intervals (C.I.) and p-values against the hypothesis of no association. Analysis was performed on a

personal computer using SPSS for Windows, version 25.0 (SPSS, Chicago, IL).

3. Results

Out of 2072 participants, 1941 (93.72%) had received at least one dose of a COVID-19 vaccine. Such a percentage is higher than that (84.06%) reported for the Italian population at the time when we closed enrollment (April 10, 2022) (https://ourworldindata.org/covid-vaccinations). Among the vaccinated participants, 79.1% had received three doses, 19.2% two doses and 1.6% one dose.

The first step of statistical analysis was exploratory and based on univariate comparisons between vaccinated and unvaccinated participants. The two groups were compared on demographic variables (i.e., age, gender, and education), scores on the five personality dimensions of the TIPI, the DPSS-R scale and the two scales of the PVD. Compared to unvaccinated participants, those who got the vaccine had higher education ($p < 0.05$), higher scores on TIPI Consciousness ($p < 0.05$), DPSS-R Disgust Sensitivity ($p < 0.05$), PVD Perceived Infectability ($p < 0.05$) and PVD Germ Aversion ($p < 0.001$) and lower scores on TIPI Extraversion ($p < 0.05$) and TIPI Openness to experience ($p < 0.01$). Male gender was associated with a higher percentage of vaccinated participants (96.2% vs. 93.1%, $p < 0.05$).

Univariate comparisons were followed by multivariate analysis to control confounding factors (i.e., variables that correlate with both the dependent variable and independent variables). Hierarchical binary logistic regression was carried out to assess the effect of individual variables on the likelihood to get the COVID-19 vaccination. We built a 3-block model including an increasing number of individual variables as predictors of vaccination. As expected, multivariate analysis confirmed only some of the significant differences found by univariate analysis. The first block included demographic variables (i.e., age, gender, and education) as predictors. The overall model was statistically significant when compared to the null model ($\chi^2 = 13.29$, df = 3, $p < 0.01$). Higher education ($p < 0.05$) and male gender ($p < 0.05$) were significant and positive predictors of vaccination, but age ($p = 0.13$) was not. The second block included the five personality dimensions measured by the TIPI as predictors. The overall model was statistically significant when compared to the null model ($\chi^2 = 31.96$, df = 8, $p < 0.001$). Higher education ($p < 0.05$), male gender ($p < 0.05$), greater TIPI Consciousness ($p < 0.05$) and lower TIPI Openness to experience ($p < 0.01$) were significant and positive predictors of vaccination. The third and final block included the DPSS-R scale and the two PVD scales as predictors. The overall model was statistically significant when compared to the null model ($\chi^2 = 79.00$, df = 11, $p < 0.001$) and correctly predicted 93.7% of cases. Higher education ($p < 0.05$), male gender ($p < 0.01$), lower TIPI Openness to experience ($p = 0.05$) and greater PVD Germ Aversion ($p < 0.001$) were significant and positive predictors of vaccination (Table 2).

Table 2
Hierarchical binary logistic regression (block 3).

COVID-19 Vaccination	B	S.E.	Exp (B) (95% C. I.)	Wald χ^2	p value
Age	−0.01	0.01	0.99 (0.97–1.00)	2.98	0.08
Gender**	−0.89	0.29	0.41 (0.23–0.72)	9.3	0.00
Education*	0.07	0.03	1.07 (1.01–1.13)	5.21	0.02
Extraversion	−0.04	0.06	0.96 (0.85–1.08)	0.47	0.49
Agreeableness	−0.00	0.08	0.99 (0.85–1.17)	0.00	0.98
Consciousness	0.11	0.07	1.12 (0.97–1.30)	2.98	0.12
Emotional Stability	0.03	0.07	1.03 (0.90–1.18)	0.15	0.70
Openness to experience*	−0.15	0.07	0.86 (0.74–1.00)	3.82	0.05
Disgust Sensitivity	0.01	0.01	1.01 (0.99–1.02)	0.58	0.44
Perceived Infectability	0.04	0.09	1.04 (0.88–1.24)	0.21	0.64
Germ Aversion**	0.52	0.09	1.68 (1.42–1.99)	36.75	0.00
Constant	0.46	0.97	1.58	0.22	0.64

*$p < 0.05$; **$p < 0.01$; Nagelkerke $R^2 = 0.10$; Hosmer and Lemeshow test: $\chi 2 = 9.82$, df = 8, $p = 0.28$; Omnibus test of model coefficient: $\chi 2 = 79.00$, df = 11, $p < 0.001$.

4. Discussion

The COVID-19 pandemic has renewed research interest for the functional utility of the behavioral immune system in modern environments. Through our evolutionary history, the behavioral immune system was a major defensive adaptation against infections because it complemented the reactive function of the physiological immune system with preventive avoidance of pathogens. Yet, there are substantial ways in which our modern environments differ from the ancestral conditions that surrounded human evolution. It is possible that the mismatch between ancestral and modern environments makes the behavioral immune system no longer useful for fighting infections. This is the opinion of Ackerman et al. (2021) who argued that the psychological reactions elicited by the behavioral immune system may have limited utility for combating pandemic diseases like COVID-19: "the behavioral immune system is obsolete for the current pandemic battle, as effective as a longbow would be in modern military combat" (p. 183).

The findings of the present study do not support Ackerman et al.'s argument. After controlling for the confounding effects of demographic and personality factors, we found a significant and positive correlation between pathogen disgust sensitivity and COVID-19 vaccine uptake. For any additional score unit on the PVD Germ Aversion scale, the odds of being vaccinated were approximately 1.68 times higher. Thus, the likelihood of being vaccinated for a participant with the highest possible score on the PVD Germ Aversion scale was approximately 12 times higher than the likelihood for a participant with the lowest possible score.

In accord with our findings, a retrospective study utilizing a national sample of U.S. adults found that those higher in disgust proneness were more likely to have received an influenza vaccine during the previous influenza season (Luz et al., 2019). Shook et al. (2022) found that, in two large national U.S. samples, greater disgust proneness was associated with greater likelihood of previous influenza vaccine uptake, lower influenza vaccine hesitancy, and greater likelihood of future influenza vaccine uptake. Data on COVID-19 vaccine are less consistent. Karlsson et al. (2022) found that pre-pandemic germ aversion was unrelated to vaccination intentions during the pandemic, whereas participants with more mid-pandemic germ aversion had slightly higher intentions to vaccinate. By contrast, Kempthorne and Terrizzi (2021) reported a positive correlation between pathogen disgust sensitivity and negative attitudes toward COVID-19 vaccination.

Two methodological features should be considered when comparing our findings with those of previous studies. First, we measured vaccine uptake, not vaccination attitudes or intentions to vaccinate as done by previous studies. Second, in our study, the possible confounding effect of general disgust sensitivity was controlled for by including into the multivariate analysis the DPSS-R scale (which was not correlated with vaccine uptake) along with the PVD Germ Aversion scale (which is a specific measure of the activation of the behavioral immune system).

Leaving apart methodological differences, the existence of discordant findings invites reflections on the complexity of the relationship between pathogen disgust sensitivity and vaccination. Because the purpose of vaccination is to protect against infectious diseases, individuals with higher propensity to experience disgust towards potential sources of pathogens could be expected to have more positive attitudes towards vaccination (Karlsson et al., 2022). Yet, some studies conducted before the COVID-19 pandemic have disconfirmed such a prediction (Clay, 2017; Clifford and Wendell, 2016; Reuben et al., 2020). A possible explanation for the negative impact of high pathogen disgust sensitivity and germ aversion on vaccination adherence is that vaccines are administered in ways that in and by themselves are cues to contamination, such as puncturing the skin, and inhalation or ingestion of a

foreign substance (Clay, 2017).

One should consider that vaccination is an evolutionary novelty not directly linked with the cues that activate the behavioral immune system. Accordingly, the intention to vaccinate is a deliberate, conscious choice which might be only partially related to individual differences in germ aversion. In effect, when studies have focused on preventive measures other than vaccination, the functional utility of the behavioral immune system for combating the COVID-19 pandemic has emerged clearly. Shook et al. (2020) found that germ aversion correlated with the frequency of preventive health behaviors such as social distancing, avoid touching face, wearing facemask, hand washing and disinfecting objects. Cox et al. (2020) reported that heightened disgust proneness before the pandemic resulted in an increased use of protective behaviors amid the pandemic. Makhanova and Shepherd (2020) found that germ aversion was negatively associated with the number of face-to-face interactions and positively associated with anxiety about social proximity.

The focus of the present study was on pathogen disgust sensitivity. However, other positive predictors of COVID-19 vaccine uptake emerged from multivariate logistic regression, all of which have been already identified by previous studies (i.e., male gender, higher education, and lower Openness to experiences). Gender and educational level were the most consistent socio-demographic predictors reported in systematic reviews. Compared to women, men are more likely to accept the vaccine. This effect was evident in several countries, and the difference was bigger in samples of health care workers than in unspecified general population samples (Zintel et al., 2022). Compared to people with high school education or below, people with a college degree or higher education were more likely to accept COVID-19 vaccination (Wang et al., 2021).

Finally, in line with the findings of two previous studies (Browne et al., 2015; Bruno et al., 2022), we found that the personality trait "Openness to experience" was negatively related to vaccine uptake. This means that participants who were more open to unusual ideas, adventurous, and non-conforming were less likely to take the vaccine than those with lower levels of Openness to experience. One possible explanation is that higher levels of Openness to experience are associated with a tendency to underestimate risks and dismiss preventive measures to avoid potentially dangerous situations.

5. Limitations

The online data collection method limits the generalizability of the findings as the recruited participants may not represent the population well and the data are susceptible to skewed demographics. In fact, women, and participants with high levels of education were over-represented in our convenience sample. Moreover, as with any survey, the data were self-reported and not verified. Because of the sensitive nature of the question of one's vaccination, it is possible that individuals with antivax beliefs declined participation or misreported their vaccination status. However, there is evidence that providing participants with an anonymous way to report their vaccination status (as we did in the present study) minimizes misreporting of COVID-19 vaccination (Wolter et al., 2022).

6. Implications and future directions

If pathogen disgust sensitivity is an emotional driver of vaccine uptake, could public health messaging use disgusting images related to the COVID-19 pandemic to reduce vaccine hesitancy? Images of individuals who are ill and display signs of sickness or images that show sources of contamination might activate the disgust system and further motivate adherence to prevention guidelines. To our knowledge, the only study that tested such a hypothesis has been conducted by Mermin-Bunnell and Ahn (2022) in a large U.S. convenience sample. They found that, among unvaccinated participants, disgusting images significantly increased willingness to be vaccinated compared to less disgusting images of COVID-19 or perks offered for COVID-19 vaccines. Despite these promising findings, there are potential drawbacks to this approach, as outlined by Seitz et al. (2020). Crude disease images could be potentially traumatic and the acceptability of using disgust eliciting messaging directed at children or phobic patients is questionable. Clearly, we need more research on the impact of disgust-eliciting messaging on public health behaviors before leveraging pathogen disgust sensitivity as an emotional driver of vaccine uptake.

An important practical implication of the results of the present study is that vaccination promotion efforts may benefit from targeting individual differences in the reactivity of the behavioral immune system, rather than exclusively targeting specific misunderstandings regarding vaccination. Efforts to counter vaccination concerns should be mindful that psychological and behavioral defenses against infection have a long evolutionary history and that such defenses continue to function in modern environments.

Informed consent: The study was carried out according to the Declaration of Helsinki. The study protocol was approved by the Ethical Committee of the Department of Dynamic and Clinical Psychology, Sapienza, University of Rome (Prot. n. 0000453 and Prot. n. 0000112). All participants provided written informed consent before participating in study-related activities.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Ackerman, J.M., Tybur, J.M., Blackwell, A.D., 2021. What role does pathogen-avoidance psychology play in pandemics? Trends Cognit. Sci. 25 (3), 177–186. https://doi.org/10.1016/j.tics.2020.11.008.

Basile, A.J., Renner, M.W., Hidaka, B.H., Sweazea, K.L., 2021. An evolutionary mismatch narrative to improve lifestyle medicine: a patient education hypothesis. Evolution, medicine, and public health 9 (1), eoab010. https://doi.org/10.1093/emph/eoab010.

Boggs, S.T., Ruisch, B.C., Fazio, R.H., 2022. Concern about salient pathogen threats increases sensitivity to disgust. Pers. Indiv. Differ. 186, 11348 https://doi.org/10.1016/j.paid.2021.111348.

Browne, M., Thomson, P., Rockloff, M.J., Pennycook, G., 2015. Going against the herd: psychological and cultural factors underlying the 'vaccination confidence gap. PLoS One 10 (9), e0132562. https://doi.org/10.1371/journal.pone.0132562.

Bruno, F., Malvaso, A., Chiesi, F., Laganà, V., Servidio, R., Isella, V., Ferrarese, C., Gottardi, F., Stella, E., Agosta, F., Filippi, M., Lorenzo, R.D., Martin, L.R., Bruni, A.C., Maletta, R., 2022. COVID-19 vaccine uptake among family caregivers of people with dementia: the role of attitudes toward vaccination, perceived social support and personality traits. Front. Psychol. 13, 923316 https://doi.org/10.3389/fpsyg.2022.923316.

Burke, P.F., Masters, D., Massey, G., 2021. Enablers and barriers to COVID-19 vaccine uptake: an international study of perceptions and intentions. Vaccine 39 (36), 5116–5128. https://doi.org/10.1016/j.vaccine.2021.07.056.

Chiorri, C., Bracco, F., Piccinno, T., Modafferi, C., Battini, V., 2015. Psychometric properties of a revised version of the ten item personality inventory. Eur. J. Psychol. Assess. 31 (2), 109–119. https://doi.org/10.1027/1015-5759/a000211.

Clay, R., 2017. The behavioral immune system and attitudes about vaccines: contamination aversion predicts more negative vaccine attitudes. Soc. Psychol. Personal. Sci. 8 (2), 162–172. https://doi.org/10.1177/1948550616664957.

Clifford, S., Wendell, D.G., 2016. How disgust influences health purity attitudes. Polit. Behav. 38 (1), 155–178. https://doi.org/10.1007/s11109-015-9310-z.

Cox, R.C., Jessup, S.C., Luber, M.J., Olatunji, B.O., 2020. Pre-pandemic disgust proneness predicts increased coronavirus anxiety and safety behaviors: evidence for a diathesis-stress model. J. Anxiety Disord. 76, 102315 https://doi.org/10.1016/j.janxdis.2020.102315.

Duncan, L.A., Schaller, M., Park, J.H., 2009. Perceived vulnerability to disease: development and validation of a 15-item self-report instrument. Pers. Indiv. Differ. 47, 541–546. https://doi.org/10.1016/j.paid.2009.05.001.

Gluckman, P.D., Hanson, M.A., Low, F.M., 2019. Evolutionary and developmental mismatches are consequences of adaptive developmental plasticity in humans and have implications for later disease risk. Phil. Trans. Roy. Soc. Lond. B Biol. Sci. 374 (1770), 20180109 https://doi.org/10.1098/rstb.2018.0109.

Gosling, S.D., Rentfrow, P.J., Swann Jr., W.B., 2003. A very brief measure of the Big five personality domains. J. Res. Pers. 37, 504–528.

Iwasa, K., Yamada, Y., Tanaka, T., 2021. Editorial: behavioral immune system: its psychological bases and functions. Front. Psychol. 12, 659975 https://doi.org/10.3389/fpsyg.2021.659975.

Karlsson, L.C., Soveri, A., Lewandowsky, S., Karlsson, L., Karlsson, H., Nolvi, S., Karukivi, M., Lindfelt, M., Antfolk, J., 2022. The behavioral immune system and vaccination intentions during the coronavirus pandemic. Pers. Indiv. Differ. 185, 111295 https://doi.org/10.1016/j.paid.2021.111295.

Kempthorne, J.C., Terrizzi Jr., J.A., 2021. The behavioral immune system and conservatism as predictors of disease-avoidant attitudes during the COVID-19 pandemic. Pers. Indiv. Differ. 178, 110857 https://doi.org/10.1016/j.paid.2021.110857.

Luz, P., Brown, H., Struchiner, C., 2019. Disgust as an emotional driver of vaccine attitudes and uptake? A mediation analysis. Epidemiol. Infect. 147, E182. https://doi.org/10.1017/S0950268819000517.

Makhanova, A., Shepherd, M.A., 2020. Behavioral immune system linked to responses to the threat of COVID-19. Pers. Indiv. Differ. 167, 110221 https://doi.org/10.1016/j.paid.2020.110221.

Martoni, R.M., Rancoita, P., Di Serio, C., Brombin, C., 2017. Validating the Italian version of the disgust and propensity scale-revised. Front. Psychol. 8, 765. https://doi.org/10.3389/fpsyg.2017.00765.

Mermin-Bunnell, K., Ahn, W.K., 2022. It's Time to be disgusting about COVID-19: effect of disgust priming on COVID-19 public health compliance among liberals and conservatives. PLoS One 17 (5), e0267735. https://doi.org/10.1371/journal.pone.0267735.

Reuben, R., Aitken, D., Freedman, J.L., Einstein, G., 2020. Mistrust of the medical profession and higher disgust sensitivity predict parental vaccine hesitancy. PLoS One 15 (9), e0237755. https://doi.org/10.1371/journal.pone.0237755.

Schaller, M., 2011. The behavioural immune system and the psychology of human sociality. Phil. Trans. Roy. Soc. Lond. B Biol. Sci. 366 (1583), 3418–3426. https://doi.org/10.1098/rstb.2011.0029.

Schaller, M., Murray, D.R., Bangerter, A., 2015. Implications of the behavioural immune system for social behaviour and human health in the modern world. Phil. Trans. Roy. Soc. Lond. B Biol. Sci. 370 (1669), 20140105 https://doi.org/10.1098/rstb.2014.0105.

Seitz, B.M., Aktipis, A., Buss, D.M., Alcock, J., Bloom, P., Gelfand, M., Harris, S., Lieberman, D., Horowitz, B.N., Pinker, S., Wilson, D.S., Haselton, M.G., 2020. The pandemic exposes human nature: 10 evolutionary insights. Proc. Natl. Acad. Sci. U.S.A. 117 (45), 27767–27776. https://doi.org/10.1073/pnas.2009787117.

Shook, N.J., Fitzgerald, H.N., Oosterhoff, B., MacFarland, E., Sevi, B., 2022. Is disgust proneness prospectively associated with influenza vaccine hesitancy and uptake? J. Behav. Med. 1–11 https://doi.org/10.1007/s10865-022-00324-3. Advance online publication.

Shook, N.J., Sevi, B., Lee, J., Oosterhoff, B., Fitzgerald, H.N., 2020. Disease avoidance in the time of COVID-19: the behavioral immune system is associated with concern and preventative health behaviors. PLoS One 15 (8), e0238015. https://doi.org/10.1371/journal.pone.0238015.

Solak, Ç., Peker-Dural, H., Karlıdağ, S., Peker, M., 2022. Linking the behavioral immune system to COVID-19 vaccination intention: the mediating role of the need for cognitive closure and vaccine hesitancy. Pers. Indiv. Differ. 185, 111245 https://doi.org/10.1016/j.paid.2021.111245.

Troisi, A., 2020. Fear of COVID-19: insights from evolutionary behavioral science. Clinical neuropsychiatry 17 (2), 72–75. https://doi.org/10.36131/CN20200207.

Troisi, A., Di Cave, D., Carola, V., Nanni, R.C., 2022. The behavioral immune system in action: psychological correlates of pathogen disgust sensitivity in healthcare professionals working in a COVID-19 hospital. Physiol. Behav. 251, 113821 https://doi.org/10.1016/j.physbeh.2022.113821.

van Overveld, W.J.M., de Jong, P.J., Peters, M.L., Cavanagh, K., Davey, G.C.L., 2006. Disgust propensity and disgust sensitivity: separate constructs that are differentially related to specific fears. Pers. Indiv. Differ. 41 (7), 1241–1252. https://doi.org/10.1016/j.paid.2006.04.021. ISSN 0191-8869.

Wang, Q., Yang, L., Jin, H., Lin, L., 2021. Vaccination against COVID-19: a systematic review and meta-analysis of acceptability and its predictors. Prev. Med. 150, 106694 https://doi.org/10.1016/j.ypmed.2021.106694.

Wolter, F., Mayerl, J., Andersen, H.K., Wieland, T., Junkermann, J., 2022. Overestimation of COVID-19 vaccination coverage in population surveys due to social desirability bias: results of an experimental methods study in Germany. Socius 8. https://doi.org/10.1177/23780231221094749.

World Health Organization, 2014. Report of the SAGE working Group on vaccine hesitancy. http://www.who.int/immunization/sage/meetings/2014/october/1_Report_WORKING_GROUP_vaccine_hesitancy_final.pdf.

Young, M., Crook, H., Scott, J., Edison, P., 2022. Covid-19: virology, variants, and vaccines. Br. Med. J. https://doi.org/10.1136/bmjmed-2021-000040, 2022.

Zintel, S., Flock, C., Arbogast, A.L., Forster, A., von Wagner, C., Sieverding, M., 2022. Gender differences in the intention to get vaccinated against COVID-19: a systematic review and meta-analysis. Zeitschrift fur Gesundheitswissenschaften = Journal of public health 1–25. https://doi.org/10.1007/s10389-021-01677-w. Advance online publication.