Is disgust proneness prospectively associated with influenza vaccine hesitancy and uptake?

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Abstract Although various demographic and psychosocial factors have been identified as correlates of influenza vaccine hesitancy, factors that promote infectious disease avoidance, such as disgust proneness, have been rarely examined. In two large national U.S. samples ($Ns = 475$ and 1007), we investigated whether disgust proneness was associated with retrospective accounts of influenza vaccine uptake, influenza vaccine hesitancy, and eventual influenza vaccine uptake, while accounting for demographics and personality. Across both studies, greater age, higher education, working in healthcare, and greater disgust proneness were significantly related to greater likelihood of previously receiving an influenza vaccine. In Study 2, which was a year-long longitudinal project, disgust proneness prospectively predicted influenza vaccine hesitancy and eventual vaccine uptake during the 2020–2021 influenza season. Findings from this project expand our understanding of individual-level factors associated with influenza vaccine hesitancy and uptake, highlighting a psychological factor to be targeted in vaccine hesitancy interventions.

Keywords Influenza · Vaccine hesitancy · Vaccine uptake · Disgust sensitivity · Personality

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Introduction

Each year in the U.S., tens of thousands of people die from influenza and hundreds of thousands are hospitalized, costing millions of dollars in medical expenses and taking a toll on the mental health of loved ones (CDC, 2020a; Molinari et al., 2007). These numbers are staggering as death and severe illness from influenza are largely preventable through vaccination (WHO, 2020). Despite the availability of annual influenza vaccines in the U.S., adult vaccination coverage rates are relatively low, ranging from 37.1% to 48.4% in the past ten years from 2010 to 2020 (CDC, 2020b). These numbers are well below the target rate of 70%, which is estimated to be necessary to significantly minimize transmission of the virus and reduce the health burden (CDC, 2020b). Increasing influenza vaccine uptake is a necessary goal for social scientists seeking to improve population health. Developing tailored and targeted interventions to improve influenza vaccine uptake requires understanding variability in vaccine hesitancy (i.e., uncertainty or unwillingness to receive a vaccine when it is available; Butler & MacDonald, 2015; MacDonald, 2015). Although some research has identified various psychosocial correlates of influenza vaccine hesitancy (see Schmid et al., 2017; Yeung et al., 2016, for reviews), very little work has examined psychological processes that are proposed to serve an infectious disease avoidance function (e.g., disgust sensitivity, referred to as disgust proneness throughout this paper; Olatunji et al., 2017). Such processes could potentially be leveraged in vaccine hesitancy interventions. The goal of the current research was to examine the extent to which disgust proneness was associated with influenza vaccine hesitancy and uptake.

Beyond contextual factors (e.g., access or having a regular healthcare provider; Jasek, 2011; Matsui et al., 2011),

several psychosocial factors have been associated with influenza vaccine hesitancy or uptake (see Schmid et al., 2017; Yeung et al., 2016, for reviews). Those who are younger (Zürcher et al., 2019), male (Mamelund & Bergsaker, 2011), single (Li et al., 2012), or non-White (Quinn et al., 2017), and those who have less education (Blank et al., 2009), have lower income (Lucyk et al., 2019), or live in socioeconomically deprived areas (Norbury et al., 2011; Sammon et al., 2012) are more likely to be vaccine hesitant. Greater dislike of needles (Ryan et al., 2019), lower perceived moral obligation to receive a vaccine (Lehmann et al., 2015), and less agreeable personality (Demir et al., 2020) have each been associated with greater influenza vaccine hesitancy. 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 (Schmid et al., 2017).

According to Behavioral Immune System theory (Schaller, 2006), the emotion of disgust is a psychological process proposed to serve an infectious disease avoidance function. The experience of disgust signals a potential pathogen threat and motivates avoidance behavior. Although a universal emotion, individuals vary in their tendency to become disgusted and the intensity with which they feel disgust (i.e., disgust proneness; Haidt et al., 1994; Tybur et al., 2009). Those higher in disgust proneness are more reactive to potential sources of pathogens and engage in more prophylactic behaviors. For example, greater disgust proneness was associated with greater fears and anxiety about Swine flu (Brand et al., 2013; Wheaton et al., 2012), as well as anxiety and concerns about COVID-19 (e.g., McKay et al., 2020; Shook et al., 2020). Those higher in disgust proneness were also more likely to engage in preventive health behaviors (e.g., handwashing, social distancing) during the 2014 Ebola outbreak (Blakey et al., 2015) and the COVID-19 pandemic (e.g., Cox et al., 2020; Shook et al., 2020). Theoretically, those higher in disgust proneness should be less vaccine hesitant and more likely to accept vaccines as a means of protecting themselves against infectious diseases. However, this basic proposition has received little empirical attention.

A recent study found that greater disgust proneness was associated with less COVID-19 vaccine hesitancy in a large national sample of U.S. adults (Shook et al., 2021). Further, a 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). This retrospective report supports the theoretical proposition that disgust proneness serves a disease avoidance function through vaccine uptake. However, additional research is necessary to replicate this finding, and prospective research is needed to demonstrate that disgust proneness *predicts* future influenza vaccine uptake.

The purpose of the current research was to examine the extent to which disgust proneness was associated with influenza vaccine hesitancy and uptake. Across two studies of national samples of U.S. adults, we sought to replicate the previous finding that disgust proneness was associated with retrospective accounts of influenza vaccine uptake. Additionally, Study 2 utilized a pre-registered, longitudinal design to test whether disgust proneness uniquely predicted influenza vaccine hesitancy and eventual vaccine uptake (see preregistration at https://osf.io/2qz4f). Overall, we expected greater disgust proneness to be associated with a greater likelihood of previously receiving an influenza vaccine, lower influenza vaccine hesitancy, and greater likelihood of influenza vaccine uptake.

Study 1

The goal of the first study was to replicate the previous finding that disgust proneness was associated with retrospective accounts of influenza vaccine uptake (Luz et al., 2019). As demographic and personality factors have been associated with influenza vaccine hesitancy, we controlled for these variables to assess the amount of variance uniquely accounted for by disgust proneness.

Method

Participants and procedure

Based on an a priori power analysis, a minimum sample size of 171 was necessary to detect a small effect size (based on Luz et al., 2019) in a regression analysis with 15 predictors, $\alpha = 0.05$, and power $= 0.80$ (GPower; Faul et al., 2009). To add precision to our analyses, a total of 500 participants were recruited through Amazon's Mechanical Turk (MTurk). Data from 25 participants were excluded from analyses due to missing scores for primary study variables. The final sample ($N = 475$) had a mean age of 41.4 years ($SD = 13.5$, range: 18 to 78) and was 53.9% female. The sample was predominantly White (68.6%), Black/African American (14.6%), Hispanic/Latinx (3.9%), and Asian (3.6%). The majority of the sample were college graduates (57.5%) and had an annual income at or below $60,000 (60.6%). Approximately 12% reported working in a healthcare field. Participants were eligible for the study if they were at least 18 years of age and U.S. residents. After providing online consent, participants completed an online survey. Questionnaires were presented

in a random order, except for demographic questions, which appeared last. Participants were compensated $2.00. Electronic consent was obtained from all participants. This project was approved by the first author's institutional review board.

Measures

Retrospective influenza vaccine uptake

Participants were asked, "Overall, do you regularly receive the annual flu shot?" Response options were Yes (coded as 1) or No (coded as 0).

Disgust proneness

Disgust proneness was measured using a composite score from three well-validated subscales that assess pathogen disgust proneness. Specifically, the Disgust scale–Revised (DS-R; Olatunji et al., 2007) is a 27-item scale. For 14 items, participants indicate how true each statement is about them or how much they agree with each statement on a scale of 1 (*Strongly disagree/very untrue about me*) to 5 (*Strongly agree/very true about me*). For 13 items, participants indicate how disgusting they would find a variety of experiences on a scale of 1 (*Not disgusting at all*) to 5 (*Extremely disgusting*). The measure has three subscales. The core disgust subscale includes 12 items (e.g., "it bothers me to hear someone clear a throat full of mucous;" $\alpha = 0.72$) and assesses disgust evoked by potential pathogen sources. The animal reminder subscale contains eight items (e.g., "it would bother me to be in a science class, and to see a human hand preserved in a jar;" $\alpha = 0.77$) and assesses disgust evoked by reminders that humans are animals. The contamination disgust subscale contains five items (e.g., "I never let any part of my body touch the toilet seat in public restrooms;" $\alpha = 0.74$) and assesses disgust evoked by potential transmission of pathogens. For the purpose of this study, only the core and contamination disgust proneness subscales were used, as these subscales are directly related to the disease avoidance function of disgust. The animal-reminder subscale does not pertain to disease avoidance concerns (Olatunji et al., 2014). Responses were averaged for each subscale, with higher scores indicating higher disgust proneness.

The Three Domain Disgust Scale was also used to assess pathogen disgust proneness (TDDS; Tybur et al., 2009). The TDDS is a 21-item questionnaire, including subscales measuring pathogen, moral, and sexual disgust proneness. The pathogen subscale directly pertains to disease avoidance and was thus used in this study. The pathogen subscale consists of seven statements (e.g., "sitting next to someone who has red sores on their arm"), and participants indicate how disgusting they find each situation on a scale of 0 (*Not at all disgusting*) to 6 (*Extremely disgusting*). Responses were averaged, with higher scores indicating higher pathogen disgust proneness ($\alpha = 0.87$).

The three measures of disgust proneness were strongly correlated with one another (rs: 0.62 to 0.69, ps < 0.001). As such, and for parsimony, we created a composite disgust proneness variable by standardizing and averaging the three scores (see Terrizzi et al., 2012; Fitzgerald et al., 2021). The general pattern of results did not differ if the individual disgust proneness scores were used in the analyses (see Supplemental Material).

Personality

The Big 5 Mini-Markers (Saucier, 1994) measure was included to assess individual differences in personality. The measure consists of 40 adjectives total, with eight adjectives representing each of the Big 5 traits: extraversion (e.g., "talkative;" $\alpha = 0.88$), openness (e.g., "creative;" $\alpha = 0.78$), neuroticism (e.g., "emotional;" $\alpha = 0.78$), conscientiousness (e.g., "efficient," $\alpha = 0.84$), and agreeableness (e.g., "cooperative;" $\alpha = 0.86$). Participants indicate on a scale of 1 (*inaccurate*) to 5 (*accurate*) how much each adjective represents them. Responses are reverse coded as necessary, and responses to adjective categories are averaged. Higher scores indicate higher levels of a given personality trait. These variables were included as covariates in the analyses, as personality has been associated with influenza vaccine hesitancy (Demir et al., 2020).

Demographics

Demographic information was collected, including gender, age, ethnicity, income, and education. Participants also indicated whether they worked in a healthcare profession (*yes* or *no*). These items were used as covariates in the analyses, as these factors have been associated with influenza vaccine hesitancy (see Schmid et al., 2017; Yeung et al., 2016, for reviews).

Analytic technique

A logistic regression model was estimated to address our primary aim. Retrospective vaccine uptake was specified as the outcome variable, and the disgust proneness composite was specified as the primary predictor variable. To isolate the association between disgust proneness and vaccine uptake, this model accounted for a range of covariates that have been linked with disgust and health behaviors in past research, including age, gender, race, income, education, working in

health care, and personality characteristics (e.g., Oosterhoff et al., 2018; Shook et al., 2020).

Results

Descriptive statistics and bivariate correlations among all study variables are presented in Table 1. Participants with higher education, with higher income, or who worked in a healthcare field were more likely to report regularly receiving an annual influenza vaccine. Those higher in disgust proneness were also more likely to report regularly receiving an annual influenza vaccine.

To determine the extent to which disgust proneness uniquely accounted for variance in retrospective influenza vaccine uptake, a binary logistic regression model was estimated (see Table 2). The disgust proneness composite, personality traits, and demographic variables were entered

Table 1 Descriptive statistics and bivariate correlations for Study 1 variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Age													
2.Gender(female)	.08												
3.Race(non-White)	−.25**	−.06											
4.Income	.06	.04	−.06										
5.Education	−.08	−.05	.08	.33**									
6.HealthCareWorker	−.25**	.01	.16**	−.02	.17**								
7.Extraversion	.09*	.02	.02	.13**	.12**	.04							
8.Agreeableness	.37**	.15**	−.25**	.01	−.20**	−.32**	.13**						
9.Conscientiousness	.33**	.13**	−.21**	.11**	−.05	−.24**	.22**	.56**					
10.Neuroticism	−.31**	.03	.11*	−.11*	.03	.17**	−.27**	−.34**	−.46**				
11.Openness	.08	.03	−.06	−.03	.07	−.03	.17**	.28**	.32**	−.21**			
12.Disgustproneness	−.07	.17**	.21**	.02	.19**	.24**	.08	−.16**	−.08	.18**	.04		
13.PreviousInfluenza-VaccineUptake	.07	.03	−.04	.14**	.19**	.25**	.03	−.04	−.04	.07	−.09	.17**	
Mean(n)	41.42	(256)	(124)	6.17	6.25	(115)	2.98	3.94	3.76	2.79	3.65	3.73	(248)
StandardDeviation(%)	13.47	(53.89)	(26)	2.90	1.57	(24.21)	0.90	0.74	0.78	0.75	0.67	0.81	(52.20)
PossibleRange	18–78	–	–	1–12	1–8	–	1–5	1–5	1–5	1–5	1–5	1.47–5.55	–

Gender coded: 0 = male, 1 = female; Race coded: 0 = White, 1 = non-White; Health Care Worker coded: 0 = no, 1 = yes; Previous influenza vaccine uptake coded: 0 = No, 1 = Yes; * $p < .05$. ** $p < .01$

Table 2 Binary logistic regression model predicting retrospective influenza vaccine uptake in Study 1

	Regular annual Influenza vaccine uptake			
	OR	SE	95% CI	p
Intercept	0.03	0.03	0.00–0.34	0.006
Age	1.02	0.01	1.01–1.04	0.008
Education (higher numbers more education)	1.23	0.09	1.06–1.42	0.005
Gender (0 = Male, 1 = Female)	0.94	0.20	0.63–1.42	0.785
Race (0 = White, 1 = Non-white)	0.68	0.17	0.42–1.10	0.117
Income (higher numbers = more income)	1.07	0.04	1.00–1.16	0.056
Work in healthcare (0 = no, 1 = yes)	3.83	1.03	2.29–6.57	< 0.001
Big 5—Extraversion	1.01	0.12	0.80–1.27	0.929
Big 5—Agreeableness	1.30	0.23	0.92–1.86	0.140
Big 5—Conscientiousness	0.95	0.16	0.68–1.33	0.758
Big 5—Neuroticism	1.23	0.19	0.90–1.68	0.199
Big 5—Openness	0.69	0.11	0.50–0.94	0.022
Disgust proneness composite	1.39	0.19	1.07–1.83	0.015
R^2	0.141			

as predictors. Older age, more education, and working in a healthcare field were each significantly associated with a greater likelihood of regularly receiving an annual influenza vaccine. Greater openness was significantly associated with a lower likelihood of regularly receiving an annual influenza vaccine. Greater disgust proneness was associated with a higher likelihood of regularly receiving an annual influenza vaccine.

Discussion

The purpose of this study was to examine the association between disgust proneness and the likelihood of receiving the influenza vaccine. Consistent with Behavioral Immune System theory, the results indicated that people who experience greater disgust proneness were more likely to report regularly receiving an annual influenza vaccine compared to those who experience less disgust proneness. These findings provide promising evidence that disgust may play a meaningful role in influenza vaccine uptake. However, there are some limitations to this study. First, participants were recruited through MTurk, and concerns have recently been raised regarding the quality of data collected through MTurk (Chmielewski & Kucker, 2020; Hauser et al., 2019). As we did not include data quality checks, the data may contain more noise and the findings may be less reliable. Second, this study was cross-sectional and examined retrospective reports of vaccine uptake. It is unclear if disgust proneness precedes vaccine uptake and establishing this temporal sequence provides a logical next step in understanding the role of disgust in influenza vaccine hesitancy.

Study 2

The goal of the second study was to replicate results from Study 1 in an independent sample recruited through different means (i.e., not through MTurk) and extend Study 1 findings by testing whether disgust proneness prospectively predicted influenza vaccine hesitancy and uptake. Study 2 utilized data from a year-long longitudinal study, in which participants were surveyed on a weekly to monthly basis from March 2020 to March 2021. In June 2020, participants reported whether they had received an influenza vaccine for the 2019–2020 influenza season and their intentions to receive an influenza vaccine for the 2020–2021 influenza season. From September 2020 to March 2021, participants reported on a monthly basis whether they had received an influenza vaccine for the current influenza season. We had four preregistered hypotheses (see https://osf.io/2qz4f):

1. Greater disgust proneness would be associated with greater likelihood of receiving an influenza vaccine in the previous influenza season.
2. Greater disgust proneness would be associated with lower likelihood of influenza vaccine hesitancy.
3. Greater disgust proneness would prospectively predict influenza vaccine uptake, directly or indirectly through lower likelihood of influenza vaccine hesitancy.
4. Greater disgust proneness would prospectively predict receiving an influenza vaccine earlier in the influenza season.

Method

Participants

This study used a subset of a larger longitudinal panel study. The broader study consisted of a national sample of 1,518 adults residing in the U.S. (51.3% women; $M_{age} = 51.80$ years, $SD_{age} = 17.23$, range: 18 to 88 years; 82% White; $Mdn_{Education} =$ College graduate; $Mdn_{Income} = $60,000–69,999$; 8% work in a healthcare field). Participants were recruited through the panel provider Qualtrics for a longitudinal study regarding the effects of COVID-19. The study consisted of 29 Waves of data collection that occurred on a weekly, bi-weekly, or monthly basis. Original sample size was determined based on Monte Carlo simulations (N = 10,000) of the most conservative models for the data analysis plan associated with the larger longitudinal project. A minimum sample of 500 was estimated to provide sufficient power (> 95%) to detect anticipated effects ($\beta = 0.15$ to 0.20) based on pilot data assuming $\alpha = 0.05$. To account for attrition or unusable data, a panel of at least 1000 U.S. individuals was desired.

For the purpose of this project, data from Wave 1, Wave 8, Wave 14, and Waves 20–29 were used. A subset of 1,007 participants completed all predictor variables (i.e., disgust proneness and demographic questions) and at least one outcome variable at these waves, and thus were retained in the analyses (51% women; $M_{age} = 55.67$ years, $SD_{age} = 15.73$, range: 20 to 88 years; 85% White; $Mdn_{Education} =$ College graduate; $Mdn_{Income} = $70,000—$79,999$; 5% work in a healthcare field).

Procedure

Participants completed online surveys on a weekly to monthly basis. This project was approved by the first author's institutional review board. Before starting the first survey, participants provided electronic consent. In the Wave 1 (March 2020) and Wave 8 (May 2020) surveys, participants provided demographic information, as described in

Study 1. In the Wave 8 survey, participants completed a measure of pathogen disgust proneness (Tybur et al., 2009), as described in Study 1. In the Wave 14 survey (June 2020), participants were asked, "Did you get a flu shot this past flu season (2019–2020)?" Response options were "Yes" (coded as 1) or "No" (coded as 0). Participants also were asked, "Will you get a flu shot for the upcoming flu season (2020–2021)?" Response options were "Yes," "Maybe," or "No." Responses of "Maybe" and "No" were coded as 0 to represent influenza vaccine hesitancy. Responses of "Yes" were coded as 1 to represent NOT vaccine hesitant. In the Waves 20–29 surveys (September 2020–March 2021), participants were asked, "Have you received a flu shot for the upcoming flu season?" Response options were "Yes," "Not Yet," or "No." Responses were aggregated to compute an influenza uptake variable, coded as 0 = not receiving an influenza vaccine and 1 = receiving an influenza vaccine. For those who received an influenza vaccine, a time variable was created to indicate at which wave participants first indicated receiving their influenza vaccine (i.e., when in the influenza season they got vaccinated). Upon completion of each survey, participants were given monetary compensation in an amount established by the panel provider.

Analytic technique

Separate logistic regression models were estimated to examine associations between disgust proneness and receiving the influenza vaccine the prior year (H1) and influenza vaccine hesitancy (H2). A mediation model was then estimated to examine whether disgust proneness was directly associated with future vaccine uptake and indirectly associated with future vaccine uptake through vaccine hesitancy (see Fig. 1; H3). Lastly, a regression model was estimated to examine associations between disgust proneness and the wave at which the influenza shot was received (Waves 20–29; H4). The wave at which a person reported that they received a vaccine was rank-ordered, such that larger numbers reflected receiving a vaccine in a later wave, and was specified as the
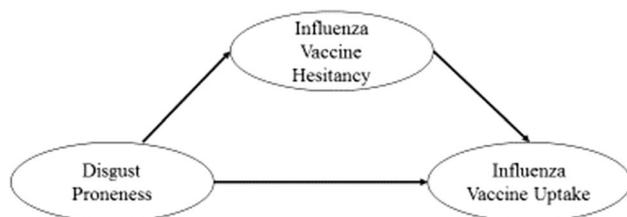

Fig. 1 Study 2 mediation model prospectively testing the direct effect of disgust proneness assessed at Wave 8 (May 2020) on influenza vaccine uptake assessed at Waves 20–29 (September 2020– March 2021) and the indirect effect through influenza vaccine hesitancy assessed at Wave 14 (June 2020)

outcome variable. All models accounted for covariates that have been related to vaccine hesitancy, including age, gender, race, income, and education (Abbas et al., 2018). Working in healthcare was also included in order to better control for effects of mandated or strongly encouraged vaccination due to employment. Analyses were conducted in the statistical programs R and MPlus. All effects were estimated using a bias-corrected and accelerated bootstrap method (Haukoos & Lewis, 2005), 5000 bootstrapped samples, and a 95% CI. All analyses were pre-registered at: https://osf.io/2qz4f.

Missing data

Patterns of missingness were analyzed using the R package naniar (Tierney et al., 2021). Based on Little's Missing Completely at Random (MCAR) test, data were not missing completely at random ($p < 0.001$). Participants with missing data ($N = 327$) were compared to complete cases ($N = 680$) using chi-square or t-test to determine if the sample differed in demographic or disgust proneness variables. Participants did not significantly differ on any of the variables ($ps > 0.75$). Multiple imputation (k = 10, N = 100) was used to address missingness and estimated with the MICE package (Van Buuren & Groothuis-Oudshoorn, 2011). To aid in the imputation process, all demographic characteristics, pathogen disgust proneness, and vaccine hesitancy variables were used to estimate missing values when present.

Results

Descriptive statistics and bivariate correlations among all study variables are presented in Table 3. Older adults, women, those with higher education, and those with higher income were more likely to have received their influenza shot in the past year, to have lower influenza vaccine hesitancy, and to have received their influenza shot in the following year. Greater disgust proneness was significantly correlated with lower influenza vaccine hesitancy and greater influenza vaccine uptake in the next year.

Separate logistic regression models were estimated to examine associations between disgust proneness and retrospective reports of receiving an influenza vaccine the prior year (H1) and influenza vaccine hesitancy (H2). Model estimates are presented in Table 4. After accounting for age, gender, race, income, education, and working in healthcare, greater disgust proneness was associated with a greater likelihood of having received an influenza vaccine the prior year. Greater disgust proneness was also associated with lower influenza vaccine hesitancy.

A mediation model was estimated to examine whether disgust proneness was directly associated with future

Table 3 Descriptive statistics and bivariate correlations for Study 2 variables

Variable	1	2	3	4	5	6	7	8	9	10
1.Age										
2.Gender	-.15**									
3.Race	-.30**	.03								
4.Education	.03	-.11**	-.03							
5.Income	.15**	-.22**	-.07*	.41**						
6.HealthCareWorker	-.18**	.04	.11**	.06	.05					
7.Disgustproneness	.02	.09**	.04	-.08***	-.03	-.01	–			
8.PastYearVaccineUptake	.28**	-.10**	-.08***	.14**	.19**	.01	.06	–		
9.VaccineHesitancy	.30**	-.10***	-.06	.09**	.19**	-.02	.08**	.82**		
10.VaccineUptake	.30**	-.09***	-.05	.11**	.15**	.02	.12**	.70**	.69**	
Mean(n)	55.67	(513)	(148)	6.36	7.93	(52)	4.17	(374)	(351)	(685)
StandardDeviation(%)	15.73	(50.94)	(14.70)	1.69	3.21	(5.16)	1.25	(37.14)	(34.86)	(68.02)
PossibleRange	20–88	–	–	1–8	1–12	–	0–6	–	–	–

Gender coded: 0 = male, 1 = female; Race coded: 0 = White, 1 = non-White; Health Care Worker coded: 0 = no, 1 = yes; Past year vaccine uptake coded: 0 = No, 1 = Yes; Vaccine hesitancy coded: 0 = Yes, 1 = No; Vaccine uptake coded: 0 = No, 1 = Yes; * $p < .05$. ** $p < .01$

Table 4 Regression Models Predicting Retrospective Influenza Vaccine Uptake and Influenza Vaccine Hesitancy in Study 2

	Past Year Vaccine Uptake				Vaccine Hesitancy			
	OR	SE	95% CI	p	OR	SE	95% CI	p
Intercept	0.03	0.01	0.01–0.08	**< 0.001**	0.04	0.02	0.02–0.11	**< 0.001**
Age	1.04	0.01	1.03–1.05	**< 0.001**	1.04	0.01	1.03–1.05	**< 0.001**
Education	1.12	0.05	1.02–1.22	**0.017**	1.04	0.05	0.95–1.14	0.363
Gender	0.83	0.12	0.62–1.11	0.203	0.85	0.12	0.64–1.13	0.261
Race	1.24	0.26	0.83–1.88	0.304	1.25	0.26	0.84–1.88	0.269
Income	1.05	0.03	1.00–1.10	**0.048**	1.10	0.03	1.04–1.15	**< 0.001**
Work in healthcare	1.77	0.59	0.93–3.50	0.089	1.22	0.38	0.67–2.27	0.532
Pathogen disgust proneness	1.25	0.07	1.12–1.40	**< 0.001**	1.17	0.07	1.05–1.30	**0.005**
R^2	0.124	0.127						

Significant effects are given in bold

Gender coded: 0 = male, 1 = female; Race coded: 0 = White, 1 = non-White; Health Care Worker coded: 0 = no, 1 = yes

vaccine uptake and indirectly associated with vaccine uptake through vaccine hesitancy (see Fig. 1; H3). After accounting for covariates, there was a significant direct effect of disgust proneness on vaccine uptake (OR = 1.20, SE = 0.08, $p < 0.001$). There was also a significant indirect effect of disgust proneness on vaccine uptake through vaccine intentions (OR = 1.07, SE = 0.03, $p < 0.001$).

A final regression model was estimated to examine associations between disgust proneness and the wave at which the influenza vaccine was received (H4). Model estimates are displayed in Table 5. After accounting for covariates, we did not find evidence of an association between disgust proneness and wave at which participants received the influenza vaccine.

General discussion

The goal of the present research was to determine whether disgust proneness was associated with influenza vaccine hesitancy and uptake. Overall, we found that greater disgust proneness was associated with greater likelihood of previous influenza vaccine uptake (Studies 1 and 2), lower influenza vaccine hesitancy (Study 2), and greater likelihood of future influenza vaccine uptake (Study 2). Importantly, we found that disgust proneness prospectively predicted influenza vaccine hesitancy and uptake, independent of demographic factors. Our findings are in line with Behavioral Immune System theory and suggest that disgust proneness may play an important role in infectious disease avoidance.

Our findings add to a very limited body of research examining the link between psychological disease avoidance processes and vaccine hesitancy or uptake. Across both studies, we replicated a previous finding that greater disgust proneness was associated with retrospective accounts of influenza vaccine uptake (Luz et al., 2019). We extended this by

demonstrating that greater disgust proneness prospectively predicted influenza vaccine hesitancy and future influenza vaccine uptake in a relatively large national sample. This is the first study to the authors' knowledge to show that disgust proneness precedes influenza vaccine hesitancy and uptake. The temporal order and control of demographic factors is crucial in isolating the unique predictive value of disgust proneness and understanding the extent to which disgust proneness contributes to influenza vaccine uptake.

Interestingly, disgust proneness was associated with future influenza vaccine uptake both directly and indirectly through vaccine hesitancy. That is, greater disgust proneness assessed in May 2020 directly predicted greater likelihood of influenza vaccine uptake during the 2020–2021 influenza season. And, greater disgust proneness was prospectively associated with lower influenza vaccine hesitancy, which in turn was prospectively associated with greater likelihood

Table 5 Longitudinal Regression Model Predicting Timing of Vaccine Uptake in Study 2

	Wave of Vaccination			
	B	SE	95% CI	p
Intercept	5.34	0.61	4.15–6.54	**< 0.001**
Age	− 0.02	0.01	− 0.04–− 0.01	**< 0.001**
Education	0.03	0.05	− 0.08–0.14	0.566
Gender	0.13	0.16	− 0.20–0.45	0.445
Race	− 0.50	0.26	− 1.01–0.02	0.058
Income	− 0.01	0.03	− 0.07–0.05	0.784
Work in healthcare	− 0.11	0.37	− 0.84–0.62	0.774
Pathogen disgust proneness	− 0.06	0.07	− 0.19–0.08	0.421
R^2/R^2 adjusted	0.032/0.021			

Significant effects are given in bold

Gender coded: 0 = male, 1 = female; Race coded: 0 = White, 1 = non-White; Health Care Worker coded: 0 = no, 1 = yes

of future influenza vaccine uptake. Thus, disgust proneness may shape vaccine hesitancy, which influences behavior, and disgust proneness may also influence health decisions in the moment. Current feelings of disgust or perceived disease threat may motivate more immediate behavior to mitigate infectious disease concerns. Additionally, the potential link between disgust proneness and vaccine hesitancy or vaccine uptake may be useful in developing interventions to encourage vaccine uptake. The emotion of disgust, a key component of disgust proneness, is universal and malleable (Batres & Perrett, 2020; Curtis et al., 2011). Thus, if disgust proneness predicts vaccine hesitancy and uptake, this may suggest a potential intervention target to decrease hesitancy and increase vaccine uptake.

We did not find evidence to suggest that disgust proneness significantly predicts when an individual will receive an influenza vaccine among those who received the vaccine. Potentially, disgust proneness may not influence timing of vaccine uptake. External factors, such as access and schedule, may have a large effect on when someone receives a vaccine. It is possible that opportunities to receive the influenza vaccine were more limited during the data collection period due to COVID-19 restrictions and fear. Specifically, COVID-19 infection rates peaked in the United States between September 2020 and March 2021 (CDC, 2021a), which was accompanied by an increased disease related threat, as well as an overburdening of the US healthcare system. These factors may have influenced when some people were able to receive their influenza vaccine or when they felt comfortable getting their shots. Furthermore, the COVID-19 pandemic may have affected participants' general perception and acceptance of influenza vaccines (Mercadante & Law, 2021). Also, due to the high amount of social distancing during this period, influenza infection rates were substantially lower than previous years (CDC, 2021b), which may have affected timing of shots.

Across both studies, we also replicated previous findings linking different demographic factors to influenza vaccine hesitancy and uptake (see Schmid et al., 2017; Yeung et al., 2016, for reviews). Specifically, older age was associated with greater likelihood of previously receiving an influenza vaccine, lower influenza vaccine hesitancy, and greater likelihood of future influenza vaccine uptake. Older age was also associated with receiving an influenza vaccine earlier in the influenza season. These findings are not necessarily surprising given the greater risk of severe illness or death from influenza for older adults (CDC, 2021c). Individuals with higher education or income were more likely to report previously receiving an influenza vaccine, and those with higher income were less likely to be influenza vaccine hesitant. Those with higher socioeconomic status are more likely to have access to and utilize healthcare services, which may explain these results. Together, our data highlight the need to tailor influenza vaccine hesitancy messaging and interventions to target younger adults, those with less education, and those with lower income.

Findings should be interpreted in the context of certain limitations. Although the longitudinal study design allowed us to test whether disgust proneness preceded influenza vaccine hesitancy and uptake, the study is still correlational and causal inferences cannot be made. Experimental methods are needed to demonstrate causality. The national sample used in this study was primarily White, so future research is needed to more closely examine correlates of influenza vaccine hesitancy and uptake in more racially and ethnically diverse populations. Like many longitudinal studies, some participants from Study 2 discontinued their participation over time. Although best practices in missing data estimation were used, as data were not missing completely at random, it is possible that results from Study 2 were affected by attrition bias. Further, our outcome variables were measured with single-item, self-report questions. Although these items demonstrate face validity, future research should capture vaccine hesitancy and uptake with a wider-range of potential measures. Finally, Study 2 data were collected during the COVID-19 pandemic. Infectious disease threat may have been more salient, which may have affected influenza vaccine hesitancy and uptake. Indeed, the proportion of our sample who reported receiving an influenza vaccine was higher than national averages in the past decade. Thus, these findings need to be replicated during non-pandemic times.

Increasing influenza vaccine uptake is a pressing public health priority. Results from this research suggest that disgust proneness may be an important and robust predictor of vaccine uptake. These findings provide promising evidence that disgust proneness and other psychosocial disease avoidance mechanisms may be leveraged in vaccine hesitancy interventions. Future research is needed to continue to examine the efficacy and feasibility of increasing disgust proneness as a means of reducing influenza vaccine hesitancy and promoting influenza vaccine uptake.

https://osf.io/wuekj/?view_only=1bc34cdbba884bac8cd0b394867222d3.

Code availability Not applicable.

Declarations

Conflicts of interest The authors report no conflict of interest.

Ethics approval Institutional ethics approvals were obtained.

Human and animal rights and informed consent This research was ethically approved by the Institutional Review Boards at the University of Connecticut and West Virginia University. The studies were performed in accordance with the criteria defined by the rules of these committees.

Consent to participate All participants provided their consent before participation.

Consent for publication None

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