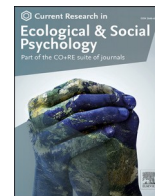


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The germ aversion paradox: When germ aversion predicts reduced alpha power suppression to norm violations

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ABSTRACT

Prior work shows that germ-averse individuals are more norm-abiding than their less germ-averse counterparts in the absence of any germ threat. However, it is unclear if germ aversion has similar effects in the presence of a germ threat. Here, we explored the hypothesis that germ-averse people would show less sensitivity to social norms because their perceived success in avoiding germs could make them feel protected from this threat. As an index of the sensitivity to norms, we assessed electrocortical reactions to another person's norm-violating behaviors. 59 young American adults were either primed with a germ threat or not. They subsequently saw either norm-violating or normal behaviors. In the control-priming condition, a reduction in upper-alpha band power in response to norm-violating (vs. normal) behaviors (signifying vigilance to norm violations) was significantly greater for those high in germ aversion, thereby conceptually replicating the prior evidence linking germ aversion to conformity. This effect, however, was significantly reversed in the threat-priming condition. The elevated level of neural reactivity to norm violations in the threat-priming condition, present for those low in germ aversion, disappeared for those high in germ aversion. Our findings suggest that although germ aversion predicts greater norm-abidance in the absence of any germ threat, this effect paradoxically reverses itself in the presence of it.

The coronavirus 2019 (COVID-19) pandemic laid bare how damaging widespread infection can be, presenting a costly reminder that germs have been one of the most potent selection pressures throughout human evolution (Diamond, 1999; Raison and Miller, 2017; Slavich and Cole, 2013). It also illustrated how the threat of germ infection may have shaped both cultural institutions (Fincher et al., 2008; Gelfand et al., 2011) and certain aspects of human psychology (Ackerman et al., 2018; Murray and Schaller, 2016; Salvador et al., 2020). One aspect of the psychology shaped by germs involves a substantial individual variation in the propensity to feel aversion or disgust toward disease cues (Duncan et al., 2009). Some are appalled by the slightest cues of potential germ contamination (e.g., stains in a drinking cup), whereas others are oblivious to such cues. This individual difference dimension is called germ aversion. In the current work, we investigated how germ aversion might modulate one's reactivity to another person's norm-violating behaviors. As we shall see, the effect of germ aversion may critically depend on the presence or absence of germ threat.

The germ aversion paradox

Germ aversion involves disgust toward and avoidance of putative germ hazards. Thus, it would seem likely that germ-averse individuals are particularly threatened by potential germ contamination, thereby they may be chronically on high alert against such contamination (Duncan et al., 2009). In the highly sanitized clean living-conditions of industrialized modern life, only those who are sufficiently concerned with potential germ contamination are likely to be alerted to germ threats. Those low in germ aversion would remain relatively oblivious to germ contamination even if it is theoretically possible.

However, because they are on high alert against germs, those high in germ aversion also may routinely engage in various behaviors to avoid germs. The evidence shows, for example, that germ-related disgust motivates both non-human animals and humans to avoid germs (Ackerman et al., 2018; Murray and Schaller, 2016; Oaten et al., 2009). As may be expected, the germ aversion subscale of the Perceived Vulnerability to Disease (PVD) Scale (Duncan et al., 2009)—a validated measure of germ aversion—predicts the reported frequency of

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risk-preventive behaviors (Shook et al., 2020) and behavioral intentions to avoid germs (Makhanova and Shepherd, 2020; Stevenson et al., 2021). Such intentions extend to health-promoting behaviors even if they are not directly relevant to pathogens (Gruijters et al., 2016). These correlational data have been substantiated by laboratory studies, which show that when a germ threat is experimentally induced, it shifts behavioral intentions in more pro-avoidant directions (Mortensen et al., 2010).

Notably, when people engage in germ-avoiding behaviors, they are likely to be assured of their safety since the chances of contracting germs are rather small, not so much because their effort to avoid germs is always effective and fail-safe (it may not be), but rather because the base rate of germ-contamination is so low in modern, clean environments. In support of this proposition, prior evidence shows that, when engaging in sanitizing behaviors, people become less responsive to germ threats (e.g., Huang et al., 2011; Prokosch et al., 2019).

Altogether, as shown in Fig. 1, germ-averse individuals are not only disgusted by germ-related hazards but also prepared for them. Accordingly, it stands to reason that germ aversion would be associated with heightened sensitivity to infection risks even when no apparent threat is present. In the absence of an identifiable germ threat, one primary effect of germ aversion is to keep people on high alert against germs so they are ready to respond in case the threat arises (as indicated by red arrows in Fig. 1).

What if a germ threat becomes highly salient? We propose that when individuals face a real germ threat, they assess the risk. Notably, their assessment of the risk may become lower when they feel protected than when they feel unprotected. This perceived protection can arise from various sources, such as social connections and support, which often attenuate reactions to threat because they offer a sense of protection (Eisenberger et al., 2007; Salvador et al., 2020; Wang et al., 2014). Similarly, maintaining daily vigilance toward germs may create a robust sense of protection. As a result, a paradoxical effect of germ aversion may emerge. Individuals high in germ aversion may perceive a heightened degree of protection when facing a real germ threat. In the absence of any real germ threat, they are ready to be alert to a pathogen threat. However, once such a threat is identified, they may fail to see the threat as sufficiently serious because of their germ-avoiding practices. In other words, they may feel assured of their safety, leading to reduced identification of the threat as such, as depicted by blue arrows in Fig. 1. Consistent with this possibility, evidence indicates that individuals who practice sanitizing behaviors become less responsive to germ threats when they perceive such threats (e.g., Huang et al., 2011; Prokosch et al., 2019).

It is worth mentioning that high alertness in the absence of any salient threat and assurance of safety in its presence are likely to be mutually reinforcing. Germ-averse individuals may feel confident in their safety assessments during subjective evaluations of risk because of their perceived effectiveness in avoiding germs, developed through their daily germ-avoiding practices. In turn, this perceived utility of habitual alertness would further motivate the continuation of the habit. This

dynamic relationship is illustrated by the bi-directional arrows linking the two boxes in Fig. 1.

Neural reactivity to others' norm-violating behaviors

In investigating the germ aversion paradox, we focus on reactions to another's norm-violating behaviors. There is a growing consensus that social norms are needed to coordinate social behaviors (Bicchieri, 2005; Henrich, 2015), making them indispensable to assure the survival and flourishing of societies, especially when facing various natural and human-made threats, such as germs and wars (Gelfand et al., 2011). Throughout human history, societies with tighter and more stringent social norms may have been more likely to survive under the conditions of persistent germ threat (Adam-Troian et al., 2021). Supporting this idea, prior work shows that historical germ prevalence is associated with contemporary levels of the tightness of a wide variety of social norms (Gelfand et al., 2011) and collectivism (Fincher et al., 2008). At the individual level, germ aversion has been shown to predict higher conformity rates (Murray and Schaller, 2012). This germ aversion effect is not limited to norms directly related to infections but extends to a diverse range of social norms (Murray and Schaller, 2012), indicating that germ aversion is linked to norm-abidance across various behaviors (see also Gruijters et al., 2016 for corroborating evidence).

One novel extension of the Murray and Schaller evidence linking germ aversion to conformity is the expectation that germ-averse individuals should show stronger reactivity to someone violating various social norms, such as "smiling at a funeral" or "cycling on a highway." However, our two-component theory of germ aversion (Fig. 1) implies that this prediction may be limited to conditions where germs have not been identified yet. In such conditions, germ aversion primarily puts the individual on high alert against *potential* threats. However, germ aversion may function very differently when infection risks are present and are subjectively and cognitively highly salient. Under these circumstances, germ aversion may paradoxically lead to a sense of assurance regarding the person's safety against potential germ contraction due to their regular engagement in germ-avoidance practices. Accordingly, germ aversion may predict a *reduced*, rather than increased, reactivity to others' norm-violating behaviors.

To assess one's reactivity to others' norm-violating behaviors, we employed two distinct electrocortical responses. The first response, known as N400, comes into play when witnessing a norm-violating behavior, leading people to take note of the violation of relevant social norms. The N400 is a negative-going event-related potential component that responds to the semantic incongruity between the observed behavior and its context, which involves the social norms associated with the situation where the behavior occurs. This component has been extensively studied in various contexts, such as sentence comprehension (Rabovsky et al., 2018), picture processing in scenic backgrounds (Goto et al., 2010), the attribution of traits to faces (Na and Kitayama, 2011), and the detection of behaviors violating social norms (Mu et al., 2015; Salvador et al., 2020; Salvador et al., 2020).

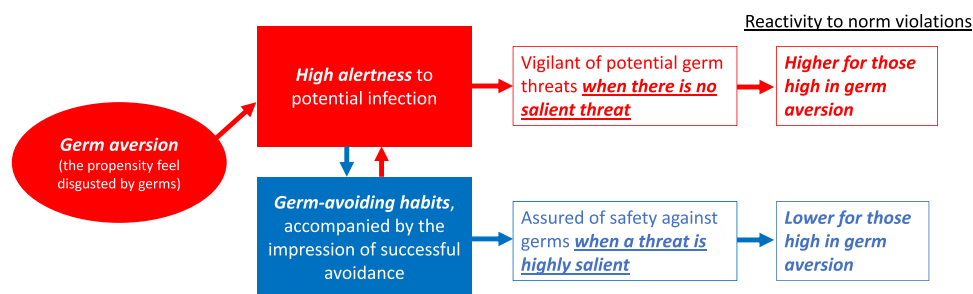


Fig. 1. The germ aversion paradox: A theory postulating two components of germ aversion (alertness to germs and preparedness to avoid germs) predicts how germ aversion modulates reactivity to others' norm-violating behaviors, depending on the presence or absence of a germ threat.

The second electrocortical measure tested in the present study involves the attention allocated to the behavior after detecting a norm violation. This process, known as vigilance, is captured by a reduction in the power of a specific frequency range called alpha (α) at the parietal region. This reduction in spectral power is called α suppression. Typically, α suppression is observed in the upper half of the α band (10.5–13 Hz) and becomes more pronounced when there are higher external processing demands (Klimesch et al., 2007; Ray and Cole, 1985). In contrast, the lower half of the α band (8–10.5 Hz, known as lower α) is more diffused topographically, and its functions are more general (Klimesch et al., 2007).

In a recent study by Salvador et al. (2020), both N400 and upper α suppression were used as measures of norm sensitivity. The participants were primed with a germ threat or not, followed by exposure to a series of norm-violating and normal behaviors. Both N400 and α suppression were assessed in response to the behaviors. Prior evidence shows that social affiliation in general (Murray et al., 2023; Young et al., 2021) and interdependent self-construal (SC) in particular (Wang et al., 2012) can mitigate the sense of a threat. Consistent with this observation, the study showed a significant interaction between germ prime and interdependent SC in determining the reactions to the norm-violating (vs. normal) behaviors. For those low in interdependent SC, both N400 and α suppression were greater for norm-violating behaviors than for normal behaviors in the threat priming condition, consistent with prior evidence that germ threat increases sensitivity to social norms. However, for those high in interdependent SC, this effect of threat disappeared, suggesting that these individuals felt protected when the threat was primed.

Present study

In the current work, we reanalyzed the Salvador et al. (2020) data and tested whether the germ aversion subscale of the Perceived Vulnerability to Disease (PVD) Scale (Duncan et al., 2009)—the most common index of germ aversion—would influence vigilance to norm violations in the presence and absence of threat. We anticipated that germ aversion would predict greater reactivity to norm-violating (vs. normal) behaviors in the control-priming condition. However, it should predict lower reactivity in the threat-priming condition. Moreover, we expected these predictions to hold for both EEG indices of threat vigilance: N400 and upper alpha suppression. In addition, as an exploratory analysis, we took note of the germ aversion subscale's composition, which comprises two distinct facets: feelings of disgust and behavioral habits or tendencies to avoid germs. Although related, these facets are conceptually distinct. We aimed to explore which facet might drive the moderating effect of germ aversion on the sensitivity to norm violations.

Methods

Participants

The fifty-nine participants from Salvador et al. (2020) were included in the present study. The sample size of this study was determined by increasing the typical sample size of prior studies with similar EEG measures by 50%. All participants were right-handed and self-identified as European American, Caucasian, or White. 21 of them were male and 38, female. They were between 18 to 30 years of age ($M = 21.38$, $SD = 2.44$). The study protocol was approved by the Institutional Review Board of the University of Michigan and all participants gave their written informed consent. Participants received either course credit or \$15 as compensation for their participation.

Procedure

Upon arrival in the lab, participants filled out pre-screening questions and a consent form. They were then asked to review “educational materials for another study,” which the experimenter said the study

team was developing. Those randomly assigned to the threat-priming condition reviewed a slideshow focusing on various infectious diseases, whereas those randomly assigned to the control priming condition reviewed a slide show about “office supplies.” After reviewing the respective slide show, participants completed a norm violation judgment task (Salvador et al., 2020). They saw a series of behaviors in various contexts and judged how violating or normal each behavior was. Salvador, Mu and colleagues prepared 34 behaviors (e.g., cycling), each of which was made normal (e.g., bike lane), weakly norm-violating (e.g., sidewalk), or strongly norm-violating (e.g., highway), depending on the context in which it was embedded. This yielded 102 unique behavior-context pairs. These 102 stimuli were presented twice, resulting in two rounds of 102 trials, 204 trials in total. The order of the stimuli was randomized in each round for each participant. These stimuli are available at this site: https://osf.io/ga96k/?view_only=f2c3741cd2eb4ae0986af39b23b81f57.

Each trial started with a fixation cross (“+”) (750 ms), followed by a verbal description of a context (e.g., bike lane) (1000ms). Another fixation point appeared for 750 ms, followed by a visual image of the context. 2000ms later, a word representing a behavior (e.g., cycling) was presented on top of the picture for 900ms. This 900ms period was the time window of interest for the measurement of electro-cortical responses. After this period, a blank screen was shown for 800ms, followed by a prompt asking participants to judge how violating the behavior was by using a 4-point scale (1 = normal, 4 = very violating). Once participants selected their response, the next trial immediately started with the presentation of a fixation cross.

After the norm violation judgment task, the participants filled out a packet of questionnaires reported elsewhere (Salvador et al., 2020). Here, we focused our analysis on the Perceived Vulnerability to Disease Scale (Duncan et al., 2009). This scale was composed of 15-items. Participants rated themselves on a 7-point rating scale (1 = strongly disagree, 7 = strongly agree). Eight of the items constitute the Germ Aversion subscale ($\alpha = 0.738$, “I prefer to wash my hands pretty soon after shaking someone’s hand”). As shown in Table 1, an examination of the items reveals that only four of the eight items address the feeling of aversion, anxiety, and disgust. The remaining items assess an intention to avoid germs. In the current sample, when we separated these items, the two components had reasonable reliabilities ($\alpha = .64$ and $.66$ for germ avoidance and the feeling of aversion, respectively). The two components were correlated only moderately ($r = .46$, $p < .001$). We ran the main analyses with the entire germ aversion subscale. To the extent that there was any effect of germ aversion, we moved on to see which of the two facets of germ aversion might drive it. The remaining seven items in the PVD Scale assessed perceived infectibility to germs ($\alpha = 0.893$, “I have a history of susceptibility to infectious diseases”). We tested the effect of this subscale for exploratory purposes.

Table 1

Two components of germ aversion: the feeling of disgust to germs and the intention to avoid germs.

Feeling of disgust	Behavioral intention
It really bothers me when people sneeze without covering their mouths.	I don't like to write with a pencil someone else has obviously chewed on.
I am comfortable sharing a water bottle with a friend. (R)	I prefer to wash my hands pretty soon after shaking someone's hand.
My hands do not feel dirty after touching money. (R)	I dislike wearing used clothes because you don't know what the past person who wore it was like.
It does not make me anxious to be around sick people. (R)	I avoid using public telephones because of the risk that I may catch something from the previous user.
R: Reverse-coded items	

EEG recording and processing

A BioSemi ActiveTwo System with 32-channel caps was used for data collection. External electrodes were included to monitor eye movements. At recording, impedances were within $\pm 20\text{k}\Omega$. The online sampling rate was set to 512Hz. The EEGLAB plugin and ERPLAB extension in MATLAB were used to analyze the data. Offline, data were resampled at 256Hz and referenced to the two mastoids. The data were filtered offline with a lowpass of 30Hz and a high pass of 0.1. A total of 1100ms epochs were extracted with a 200ms pre-stimulus baseline and 900ms post-response period. Ocular artifacts were corrected (Gratton et al., 1983) and trials were removed if they exceeded $\pm 150\mu\text{V}$ threshold as determined with a 400ms moving window using a 100ms stepwise peak-to-peak threshold, fluctuated more than $30\mu\text{V}$ between two sampling points, or if they had little to no activity (less than $\pm .5\mu\text{V}$) over the course of the trial (Luck, 2014). In the end, each Behavior type condition had at least 50% of usable trials, with the average of 95% of trials included across all participants.

Measurement of N400

To extract the N400, we first baseline-corrected the data to 200ms prior to the presentation of stimulus behaviors. As in prior work, we observed a negative-going deflection approximately 440ms after the onset of each behavior in the central sites. To be consistent with Salvador et al. (2020), we used Cz for analyses and extracted the data by extracting the mean amplitude using a time window $\pm 50\text{ms}$ around the average peak latency (390–490ms). The mean amplitude for this time window was the primary dependent variable.

Measurement of upper α -band suppression

To measure the upper α -band power, several steps were taken. We performed a time-frequency analysis (TFA) with a moving window approach. To obtain large enough segments of data, we mirrored the original data epochs (Cohen, 2014). Specifically, we duplicated, reversed along the x-axis (time), and attached to the end of the original epoch. The mirroring approach allowed us to include more data in the analysis and avoid edge artifacts in the TFA (Cohen, 2014), while also reducing the influence of DC (or “direct current”) drifts (baseline variation of low-frequency waves). The final EEG data segment was from -4043 to 4742ms. Next, we ran a TFA using complex Morlet wavelets (Cohen, 2014), which were 3 cycles wide at .5Hz and 36 cycles wide at 30Hz. Then, we extracted 473 log-spaced frequencies between .5 and 30Hz. To do so, we estimated 400 time points between -700 and 1400ms and used zero-padding to a factor of 8.

There was a 200ms baseline time window for each trial. The event-related spectral perturbation (ERSP) was calculated by taking the average of the upper α -band frequency range (10.5–13Hz) between 400ms and 900ms post-stimulus onset. Consistent with prior work (Klimesch et al., 2007), this effect was most pronounced at the midline parietal sites, thus we selected Pz as in prior work for further analyses during the 400-900ms time window of interest.

Results

Self-report measures

The germ aversion and perceived infectability subscales had the means of 3.60 and 3.23 (with the SDs of .99 and 1.16), respectively. When these means were analyzed by Prime, the Prime main effect was negligible for both subscales, $F_s < 1$. These two scores were moderately correlated at $r = .41$. We also tested whether we might find any effects of our independent variables on perceived severity of norm-violations. In a mixed general model regression with two manipulated variables (Behavior type \times Prime) and one continuous variable (Germ Aversion)

performed on the perceived severity of norm violation for each of the two rounds separately, only the main effect of Behavior type was significant, $F(2, 53) = 715.29, p < .001, \eta_p^2 = .931$ and $F(2, 53) = 610.94, p < .001, \eta_p^2 = .919$ for the first and second rounds, respectively. Across the two rounds, the normal, weakly violating and strongly violating behaviors were all rated as significantly different from each other ($M_s = 1.09, 2.10$ and 2.91), $p_s < .001$. The remaining effects did not reach statistical significance, $p_s > .519$, indicating that the norm violation manipulation was successful.

N400

Fig. 2 displays waveforms at Cz for norm-violating and normal behaviors. N400 (highlighted in gray) is visibly greater (i.e., more negative, or less positive) for norm-violating than normal behaviors. Our prediction implies that the effect of norm violation on the N400 would be moderated by both Prime and Germ Aversion. To test this prediction, we analyzed N400 in response to behaviors that vary in norm violation (strongly violating and weakly violating vs. normal). As in Salvador et al. (2020), we first performed a preliminary analysis focusing on the strong vs. weak norm-violating behaviors. The magnitude of norm violation showed no main effects nor interactions with other variables, $p_s > .07$. We thus collapsed the two norm-violation conditions. Further, another analysis with Round showed no effect of this variable. We thus performed a mixed general model regression with two manipulated variables (Behavior type \times Prime) and one continuous variable (Germ Aversion) on the magnitude of the N400 combined across the two rounds. This analysis showed the main effect of Behavior type, indicating greater sensitivity to norm-violating behaviors across participants, $F(1, 55) = 10.24, p = .002, \eta_p^2 = .157$. Importantly, the 3-way interaction involving Behavior type, Prime, and Germ Aversion was

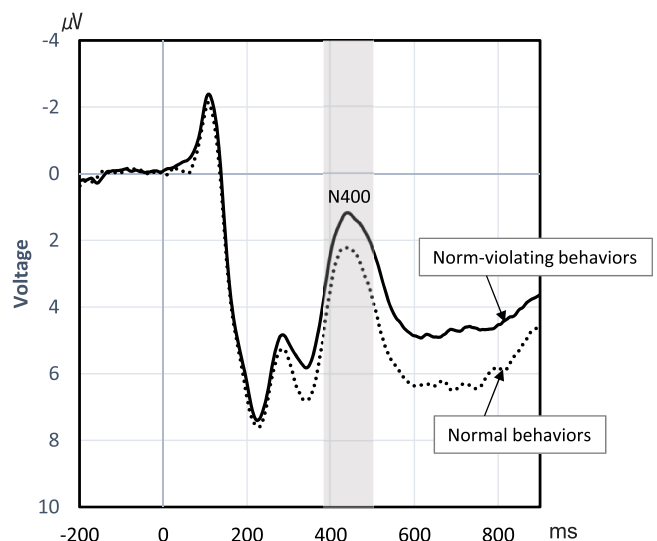


Fig. 2. Waveforms for norm-violating and normal behaviors at Cz. The time window for N400 is highlighted in gray.

not significant, contrary to predictions, $F(1, 55) = .55, p = .46, \eta_p^2 =$

.010.¹ The results did not change when the perceived infectibility subscale of the PVD scale was used as a covariate.

The same analysis was repeated for exploratory reasons with perceived infectibility. As in the analysis with germ aversion, there was a main effect of Behavior type, $F(1,55) = 11.92, p = .001, \eta_p^2 = .178$. There was no three-way interaction for Behavior type, Prime and Perceived Infectability, $F(1,55) = .23, p = .635, \eta_p^2 = .004$. However, there was a Behavior type \times Perceived Infectability interaction, $F(1,55) = 6.54, p = .013, \eta_p^2 = .106$. As shown in Fig. 3, those low in Perceived Infectability showed a greater N400 to norm-violations ($M = 2.37, SE = .89$) than normal ($M = 4.18, SE = .90$) behaviors, $F(1,55) = 17.62, p < .001, \eta_p^2 = .243$. The comparable effect was not significant for those high in Perceived Infectability, who instead appear sensitive to both types of behaviors, $F(1,55) = .368, p = .546, \eta_p^2 = .007$. Thus, the effect of perceived infectibility was apparent only for normal behaviors. We will return to this observation in the discussion section. The results did not change when the germ aversion subscale of the PVD scale was used as a covariate.

Upper α suppression

Analysis by germ aversion

We next tested whether upper α suppression varied depending on peoples' level of germ aversion. This analysis was followed with an ancillary analysis by two separable components of germ aversion: i.e., behavioral intention to avoid germs and the feeling of disgust toward germs (see Table 1 for items).

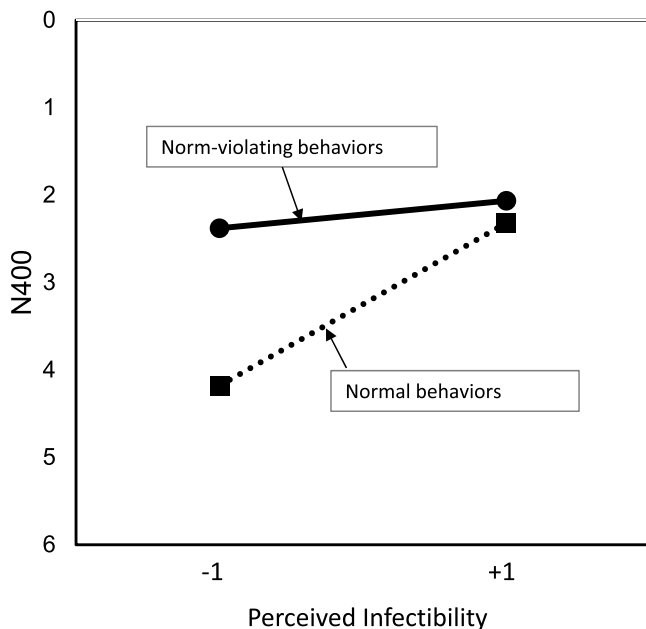


Fig. 3. The N400 magnitude for norm-violating and normal behaviors by perceived infectibility.

¹ The analysis was repeated, this time including Interdependent self-construal and its' interaction with Prime as controls. The interaction between Prime, Germ Aversion and Behavior type remained negligible, $F(1,55) = .016, p = .900, \eta_p^2 = .000$. The interaction between Prime, Interdependence and Behavior type was highly significant, $F(1,55) = 10.07, p = .003, \eta_p^2 = .160$. This latter effect indicates that the Salvador et al. (2020) evidence on the same interaction is robust after controlling for Germ Aversion. The correlation between Germ Aversion and Interdependence was significantly positive although only moderate ($r = .286, p = .028$).

Our prior investigation of upper α suppression had shown that threat priming caused the suppression effect only during the first block, when each behavior was presented for the first time (Salvador et al., 2020). In the second block, the threat effect was absent, due plausibly to implicit learning that the behaviors, even those involving norm violations, were "safe." Hence, unlike in the analysis of N400, the analysis on upper α suppression focused on the first block only. As previously reported and reproduced in Fig. 4A, upper α suppression (indicated by blue) emerged at Pz around 400ms post-stimulus and lasted while the stimulus behavior was on the screen.

We performed a mixed general model regression with two manipulated variables (Behavior type \times Prime) and one continuous variable (Germ Aversion) on upper α suppression. None of the results below changed when the perceived infectibility subscale of the PVD scale was included as a covariate. The relevant means are shown in Fig. 4B. Upper α suppression was greater (i.e., higher on the y-axis) for norm-violating than normal behaviors as shown by a main effect of Behavior type, $F(1,55) = 10.17, p = .002, \eta_p^2 = .156$. Importantly, this was qualified by a 3-way interaction involving Behavior type, Prime, and Germ Aversion, $F(1,55) = 9.22, p = .004, \eta_p^2 = .144$.² To decompose this interaction, a separate 2×2 ANOVA (Behavior type \times Germ Aversion) was performed on each of the two priming conditions.

First, in the control priming condition, the main effects of Behavior type and Germ Aversion were statistically negligible, $F(1,26) = 2.68, p = .114, \eta_p^2 = .093$ and $F(1,26) = .60, p = .45, \eta_p^2 = .023$, respectively. However, the interaction between Behavior type and Germ Aversion was statistically significant, $F(1,26) = 6.75, p = .015, \eta_p^2 = .206$. For those 1SD above the mean in Germ Aversion, upper α suppression was significantly higher for norm-violating behaviors than for normal behaviors, $F(1,26) = 9.39, p = .005, \eta_p^2 = .270$. This effect disappeared for those 1SD below the mean in Germ Aversion, $F(1,26) = .367, p = .550, \eta_p^2 = .014$. Upper α suppression was no greater for norm-violating behaviors than for normal behaviors. From another perspective, the effect of Germ Aversion was significantly negative (predicting greater upper α suppression) for the norm-violating behaviors, $r(28) = -.45, p = .015$. But there was no effect of Germ Aversion for the normal behaviors, $r(28) = .11, p = .58$.

Second, in the threat priming condition, the main effect of Behavior type was significant, $F(1,29) = 8.45, p = .007, \eta_p^2 = .226$. There was greater upper α suppression for norm-violating behaviors than for normal behaviors. The main effect of Germ Aversion was statistically negligible, $F(1,29) = .469, p = .50, \eta_p^2 = .016$. The interaction between Behavior type and Germ Aversion was statistically marginal, $F(1,29) = 2.95, p = .097, \eta_p^2 = .092$. For those 1SD below the mean in Germ Aversion, upper α suppression was significantly higher for norm-violating behaviors than for normal behaviors, $F(1,29) = 11.11, p = .002, \eta_p^2 = .277$. This effect disappeared for those 1SD above the mean in Germ Aversion, $F(1,29) = .536, p = .470, \eta_p^2 = .018$. For these participants, upper α suppression was no greater for norm-violating behaviors than for normal behaviors. From another perspective, the effect of Germ Aversion was marginally positive (predicting marginally less upper α suppression) for the norm-violating behaviors, $r(31) = .30, p = .097$. But there was no effect of Germ Aversion for the normal behaviors, $r(31) = .009, p = .96$.³

We also tested whether the effects of germ aversion extended to

² Consistent with the earlier work showing no effect of threat on alpha suppression in the second block (Salvador, Kraus et al., 2020), the same 3-way interaction involving Behavior type, Prime, and Germ Aversion was not significant for the second block, $F(1,55) = 1.48, p = .228, \eta_p^2 = .026$.

³ When we included Interdependent self-construal and its interaction with Prime as controls, the interaction between Prime, Germ Aversion and Behavior type remained significant, $F(1,55) = 6.31, p = .015, \eta_p^2 = .106$. The interaction between Prime, Interdependence and Behavior type became marginal in this analysis, $F(1,55) = 3.13, p = .083, \eta_p^2 = .056$.

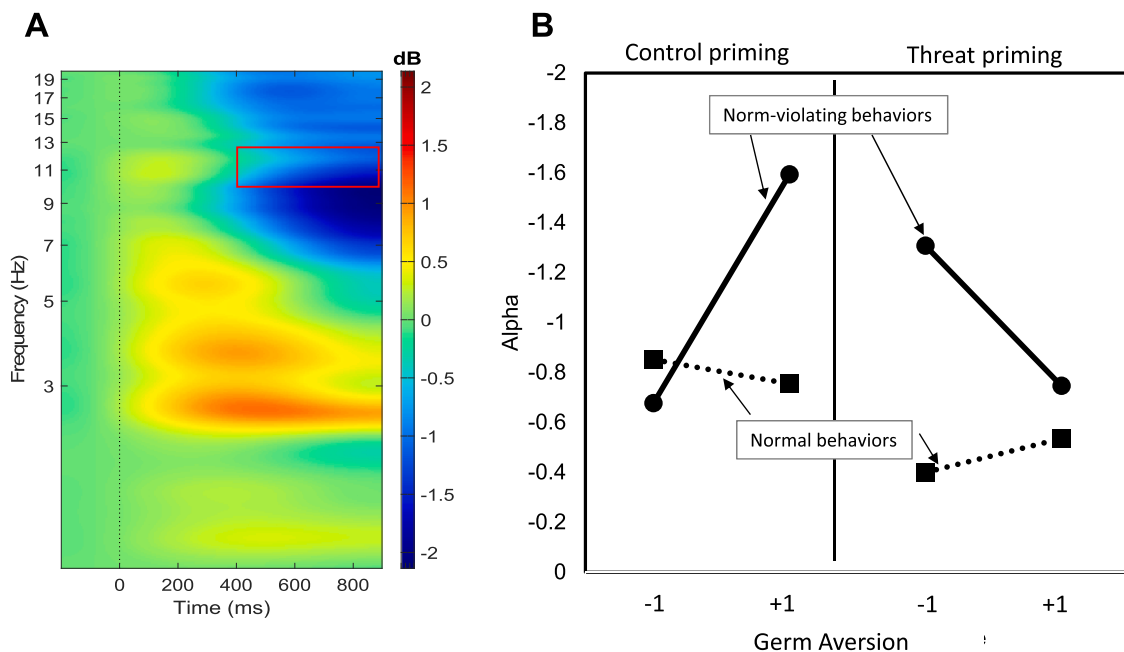


Fig. 4. A. The time frequency plot at Pz. The upper α band range of interest is indicated by the red square. B. The upper α band power for norm-violating and normal behaviors by germ aversion in the threat and control priming conditions.

Perceived Infectability. There was no Behavior-type \times Perceived Infectability interaction for either the first or second round of stimulus presentation, $F(1,55) = 1.05, p = .311, \eta_p^2 = .019$ and $F(1,55) = 1.30, p = .259, \eta_p^2 = .023$, respectively. This result did not change when the germ aversion subscale of the PVD scale was used as a covariate.

Ancillary analysis

Which of the two components of Germ Aversion might drive the Behavior type \times Prime \times Germ Aversion interaction, shown in Fig. 4B? When we ran the same analysis with the disgust component of Germ Aversion, the same 3-way interaction was somewhat weaker and yet still statistically significant, $F(1, 55) = 4.75, p = .034, \eta_p^2 = .080$. When we used the avoidance component of Germ Aversion, the 3-way interaction was highly significant, $F(1, 55) = 8.14, p = .006, \eta_p^2 = .130$. When the two 3-way interactions were entered simultaneously, only the 3-way interaction involving the avoidance component of Germ Aversion proved significant, $F(1, 53) = 4.13, p = .047, \eta_p^2 = .072$. The 3-way interaction involving the disgust component was no longer significant, $F(1, 53) = 1.06, p = .309, \eta_p^2 = .020$.

Discussion

The paradox explained

The key contribution of our work was to uncover what we refer to as the “germ aversion paradox.” First, in the control-priming condition, we observed a straightforward effect of germ aversion. Individuals high in germ aversion exhibited stronger vigilance to norm violations, indicating heightened alertness to potential germ contamination when no immediate threat was present. This evidence conceptually replicates an earlier finding by Murray and Schaller (2012), linking germ aversion to increased conformity. Notably, in all these studies, the norms at issue are not directly related to infection per se. This fact bolsters the hypothesis that threats typically call for effective social coordination by tightening social norms of all sorts (Fincher et al., 2008; Gelfand et al., 2011; Murray and Schaller, 2016).

Second, we found a paradoxical effect of germ aversion in the threat-priming condition. In this condition, the pattern observed in the control-

priming condition was significantly reversed. Specifically, individuals low in germ aversion showed greater upper- α suppression in response to norm-violating behaviors compared to normal behaviors, indicating heightened reactivity to norm violation when a germ threat was primed. However, as germ aversion increased, this effect became less pronounced. For those high in germ aversion, there was no evidence that norm-violating behaviors induced any more vigilance, compared to normal behaviors. Our findings are consistent with the two-component model of germ aversion (shown in Fig. 1), which proposes that germ aversion predicts higher alertness to potential germ contraction in the absence of a threat. However, the model also suggests that germ aversion leads to a sense of protection when a germ threat is subjectively salient.

Our work is the first to demonstrate that germ aversion has diametrically opposite effects on reactivity to others’ norm-violating behaviors, depending on the presence or absence of a germ threat. This evidence is consistent with a prior claim linking germ aversion to higher conformity rates in the absence of any germ threat (Murray and Schaller, 2012). Our study extends this evidence by suggesting that germ aversion should predict *less* conformity in the presence of a germ threat. While such a prediction has yet to be tested directly, our analysis suggests that the consideration of individual differences in germ aversion proves critical for uncovering the effect of germ threat priming. Notably, the main effect of germ threat priming was negligible in our study. Thus, if we had omitted germ aversion from our measures, we would have overlooked the robust effect of germ threat priming and erroneously concluded the influence of this priming on norm abidance is insignificant.

In an extensive series of experiments involving priming manipulations similar to the germ threat priming in our study, van Leeuwen and colleagues (2023) concluded that there was “only limited support for the hypothesis that experimentally increasing [a] pathogen [threat] influences conformity” (page 1, van Leeuwen et al., 2023). Although these authors are correct that germ threat priming does not always *increase* conformity, they did not include germ aversion in their design. Consequently, they might have missed the possibility that this priming could also decrease conformity for those who are sufficiently germ-averse (and thus germ avoidant) and feel they are well protected when facing a real

germ threat and assessing their risk.

The processing of norm violations

Two subsidiary observations are relevant to our discussion. First, the norm violations investigated in our work (e.g., smiling at a funeral and cycling on a highway) were hardly related to pathogen infections. Despite this, individuals' reactivity to these norm violations varied systematically by both germ priming and individual differences in germ aversion. This finding aligns with earlier evidence linking germ threat to the tightening of a wide range of social norms (Gelfand et al., 2011). Second, we found preliminary evidence that the interaction pattern was driven primarily by the avoidance component of germ aversion. This evidence is consistent with the hypothesis that individuals' habitual avoidance of germs provides a sense of protection and safety when a germ threat is subjectively imminent and cognitively salient. Simultaneously, those who practice habitual germ avoidance may perceive their efforts as successful, reinforcing their habitual alertness to potential germ contamination in the absence of any apparent danger of germ contraction.

In our current work, we observed a Prime x Germ Aversion effect for the upper- α suppression measure, indicating vigilant attention, but not for the N400 measure. Initially, we hypothesized that both N400 and upper- α suppression would equally serve as valid indices of the threat effect, but our findings suggest that this hypothesis needs revision. The N400 effect occurs when there is a discrepancy between an expectation and an observed event, indicating the degree to which observed behaviors deviate from social norms. While unexpected, the observation that the N400 effect occurs regardless of germ priming or the individual difference in germ aversion lends itself to a sequential processing model for norm-violating behaviors: once a behavior is encoded and compared to the social norm that is activated, a norm violation may be detected, as shown by an increase in N400. Once the violation is detected, vigilant attention may be applied to it, as indicated by upper- α suppression.

Our findings suggest that the observed interaction between germ priming and the individual difference in germ aversion may specifically occur during the vigilant attention stage of processing. Remarkably, germ-averse individuals in the germ-threat priming condition were found to register the norm-violating status of behaviors, despite not showing evidence of vigilant attention. This finding demonstrates that it is not true that germ-averse people were merely distracted from norm-violating behaviors when they were primed with a germ threat. To the contrary, these individuals take note of a norm violating happening. Despite the potential peril of a norm violation, especially when a germ threat is imminent, germ-averse individuals appear convinced of their safety likely due to their perceived previous successful experiences in avoiding germs. Bear in mind, however, that it is probably naïve to consider these inferences taking place online. Rather, it is more plausible that previous conditioning under similar circumstances influenced germ-averse individuals to lower their guard. Consequently, they were not alarmed by a norm violation, even though they registered it. Moving forward, more work is needed to examine conditions in which the effects in the two measures diverge (as in the present work) or converge (as in previous work by Salvador et al., 2020).

The psychological unconscious

One notable strength of our work was to use a neural measure of vigilant attention to norm violations, which revealed how germ aversion modulates this attention in diametrically opposite directions, depending on the presence or absence of a subjectively real germ threat. This neuroscience method enabled us to suggest that the modulating effects shown here are automatic, spontaneous, and possibly even barely conscious, rather than deliberate or strategic. We may suggest that germ-averse individuals are on high alert for possible germ contamination even without fully recognizing it, while simultaneously acting as

if they are protected. Thus, as suggested by numerous earlier researchers (Bargh and Morsella, 2008; Kihlstrom, 2008; Nisbett and Wilson, 1977; Shevrin and Dickman, 1980), the psychological unconscious may be quite rich and, in an important way, highly intelligent in the sense that it acts in ways that "make sense" given its prior experiences, ultimately serving adaptive purposes.

This apparent intelligence and adaptiveness of the psychological unconscious, as observed in the germ aversion paradox, may arise from the brain's remarkable ability to undergo plastic changes in response to the demands, affordances, and constraints presented by complex social and cultural environments. Kitayama and Salvador (2017) have highlighted the role of cultural contexts in shaping cognitive and behavioral processes. Here, we have extended this analysis to germ aversion and avoidance and their consequences on norm processing. As individuals navigate their daily lives, their interactions with the environment, including exposure to germ infection risks, contribute to the formation and refinement of mental processes and behavioral patterns. These processes may involve the integration of social norms, individual experiences, and cognitive representations related to germs and disease.

More work along this line is needed to further understand the functioning of the psychological unconscious as it is shaped by daily experiences, including those involving germ infection risks. By carefully analyzing these processes, we may gain valuable insights about the underlying mechanisms that drive human behavior and decision-making in various situations, ultimately contributing to a more comprehensive understanding of human psychology and its interaction with the environment.

Perceived infectibility

In our study, we primarily focused on the Germ Aversion subscale of the Perceived Vulnerability to Disease (PVD) Scale. However, we also observed an interesting effect of the perceived infectibility subscale on the N400 measure. Specifically, we found that the effect of norm violation on N400 was significant for those low in perceived infectibility but not for those high in it. In fact, the effect of perceived infectibility was apparent in N400 for normal behaviors but not for norm-violating behaviors. This pattern held regardless of the pathogen priming manipulation.

One plausible explanation for the observed effect of perceived infectibility on norm sensitivity is that individuals high in perceived infectibility may be less tolerant of deviations from social norms. Previous research by Young et al. (2011) has suggested that people who perceive themselves as highly susceptible to infections may exhibit greater vigilance and concern about potential dangers in their environment. This heightened vigilance could extend to social norms, as deviations from established norms might be perceived as potential risks that could lead to increased exposure to infectious diseases. Moreover, individuals high in perceived infectibility have a history of experiencing more infectious diseases, which could contribute to their heightened vigilance and wariness towards potential dangers. As proposed by Makhanova and Shepherd (2020), such individuals may develop a habitual state of alertness, constantly scanning their surroundings for any cues of potential risk and lowering the threshold for responding (i.e., exhibiting greater bias). Thus, even seemingly normal behaviors, like cycling on a bike lane, may trigger extra processing as they search for any possible deviations from established norms that could pose a threat to their health.

This heightened state of vigilance and the tendency to be alert to norm violations could be described as a form of paranoia against potential risks and dangers, which may be shaped by individuals' experiences and perceived vulnerability to infections. Investigating this aspect further in future research could shed light on the interplay between perceived infectibility, norm sensitivity, and risk perceptions, and how these factors collectively influence human behavior and decision-making in various contexts.

Limitations and conclusion

We wish to acknowledge some limitations of the present work. First, while we found support for our predictions by examining one neural index of norm sensitivity (i.e., upper- α suppression), it is important for future work to investigate downstream consequences on subjective experiences and behaviors. Additionally, exploring other measures of norm sensitivity, for example conformity to social norms (Murray and Schaller, 2012) or punishment as alternative indices of norm sensitivity (Schachter, 1950) would provide a more comprehensive understanding of the effects observed.

Second, in our study, we solely relied on an individual difference measure of germ aversion. As noted, this measure has been previously linked to germ avoidance behaviors and perceptions of infection risk. Future work should consider directly manipulating the engagement in hygienic behaviors to examine its impact on norm sensitivity. For instance, researchers could design experiments where participants are exposed to a pathogen threat or prime, and then asked to engage in specific hygienic behaviors, such as wiping a computer keyboard or washing their hands. Relatedly, future work should employ other converging measures to further investigate the hypothesis that germ-averse people “lower their guard” under threat. For example, it will be informative to use indices of threat reactivity, such as electromyograms and electrodermal responses, to examine whether their reactivity to a threat would become lower when a threat was primed.

Third, our work focused on a well-educated and wealthy segment of young adults in a modern, industrialized nation (i.e., European American college undergraduates in the U.S.). To enhance the generalizability of our research, future studies should aim to extend the investigation to diverse populations in regions where public sanitation is less assured. Different cultural contexts and varying levels of access to sanitation and healthcare may influence individuals’ perceptions of germ threats and their responses to norm violations. For example, in regions with limited access to clean water or healthcare facilities, individuals may exhibit different levels of germ aversion and norm sensitivity compared to those in more developed areas.

Fourth, it remains to be seen whether the theoretical analysis depicted in Fig. 1 could extend beyond the cultural boundary. For example, we hypothesized that the perceived success in germ avoidance is a key element in lowering the guard of germ-averse people, thereby producing apparent complacency. However, it is crucial to investigate whether this effect might go beyond cultures, such as the U.S. and other Western contexts, that unconditionally sanction successful experiences of the self rather than doubting them (Salvador et al., 2021). Exploring this in a broader global context would enrich our understanding of the underlying mechanisms (Kitayama et al., 2022b).

In conclusion, while our work provides valuable insights into the germ aversion paradox and its effects on norm sensitivity, addressing these limitations in future research will contribute to a more comprehensive and nuanced understanding of this intriguing phenomenon. As researchers continue to dive into this topic, they will undoubtedly uncover new avenues of exploration that will shed light on the complex interplay between germ aversion, threat vigilance, and norm-related behaviors.

Ethics & Informed Consent Statement

We followed all ethics requirements and standards. We also ensured that all participants voluntarily consent to participate in the study reported in this paper by filling an IRB-approved informed consent form. The study had an IRB approval at the University of Michigan.

Declaration of Competing Interest

None of the authors has any conflict of interest, financial or otherwise, regarding the paper’s content.

Data availability

Data will be made available on request.

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