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Personality and Individual Differences 176 (2021) 110787

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

# Exploring the association between compliance with measures to prevent the spread of COVID-19 and big five traits with Bayesian generalized linear model

Hyemin Han *

*Educational Psychology Program, University of Alabama, United States of America*

ARTICLE INFO

*Keywords:*
COVID-19
Preventive measures
Physical distancing
Social distancing
Big five
Big data
Bayesian analysis
Data-driven analysis

ABSTRACT

Research has examined the association between people's compliance with measures to prevent the spread of COVID-19 and personality traits. However, previous studies were conducted with relatively small-size datasets and employed frequentist analysis that does not allow data-driven model exploration. To address the limitations, a large-scale international dataset, COVIDiSTRESS Global Survey dataset, was explored with Bayesian generalized linear model that enables identification of the best regression model. The best regression models predicting participants' compliance with Big Five traits were explored. The findings demonstrated first, all Big Five traits, except extroversion, were positively associated with compliance with general measures and distancing. Second, neuroticism, extroversion, and agreeableness were positively associated with the perceived cost of complying with the measures while conscientiousness showed negative association. The findings and the implications of the present study were discussed.

## 1. Introduction

Research has found that implementation of preventive measures, such as social and physical distancing, significantly decreases the spread of COVID-19 (Thu et al., 2020). Unfortunately, implementing such measures can negatively influence economy and well-being, and be perceived as costly efforts (Atalan, 2020). Thus, people's intent to comply with the measures is necessary for effective containment of COVID-19. Given compliance has become a significant factor in efforts to deal with COVID-19 (Chang et al., 2020), it would be informative to examine the association between people's personality traits and compliance to better understand the mechanisms of spread prevention from the perspective of personality psychology.

Personality psychologists have examined whether and how personality traits are associated with compliance in diverse domains of human lives. In previous studies, the association between the Big Five personality traits and compliance in general has been investigated in diverse contexts (Allen & Walter, 2018; Clarke & Robertson, 2005). Given compliance motivation is considered to emerge from risk aversion and prosocial tendency (D'Attoma et al., 2020; Eisenhauer, 2008), we may consider how personality traits are associated with the aforementioned two factors to better understand the relationship between the traits and compliance.

First, researchers have suggested that the Big Five personality traits are related to one's tendency to avoid risk by not involving in risky behaviors. In the domain of potentially risky sexual behavior, a previous empirical study and meta-analysis reported that high extroversion showed a significant positive association with risk taking while agreeableness, openness, and conscientiousness showed a negative association (Allen & Walter, 2018; Ingledew & Ferguson, 2007). The similar pattern was found in risky driving. A meta-analysis showed that risky driving is positively associated with extroversion and negatively associated with agreeableness and conscientiousness (Clarke & Robertson, 2005). Given these previous studies, we can expect that risk aversion would be negatively associated with extroversion, so it would also be negatively associated with compliance motivation to avoid potential risks. On the other hand, agreeableness, openness, and conscientiousness can be considered as traits positively associated with compliance.

Second, we can also consider the possible association between personality traits, prosocial tendency, and compliance. Several previous studies have examined how Big Five personality traits and prosocial tendency, such as prosocial and moral motivation, ethical leadership, are related. At the conceptual level, Roberts et al. (2014) proposed that conscientiousness is fundamentally related with rule abiding tendency,

* University of Alabama, Box 870231, Tuscaloosa, AL 35487, United States of America.
*E-mail address:* hyemin.han@ua.edu.

https://doi.org/10.1016/j.paid.2021.110787
Received 12 January 2021; Received in revised form 14 February 2021; Accepted 18 February 2021
Available online 23 February 2021

self-control, and finally, morality and virtue. An empirical study also demonstrated that conscientiousness was significantly associated with ethical leadership (Kalshoven et al., 2011). Moreover, other studies have reported that agreeableness and openness were also commonly related to prosocial motivation and behavior (e.g., Carlo et al., 2005; Kline et al., 2019). These previous studies suggest that agreeableness, openness, and conscientiousness that significantly predict prosocial tendency. Given that prosocial tendency becomes a source of compliance (D'Attoma et al., 2020; Eisenhauer, 2008), we may assume that the aforementioned traits would be significantly associated with compliance.

Recent studies have examined how personality traits in terms of the Big Five personality traits were associated with compliance with preventive measures during the pandemic. Carvalho et al. (2020) demonstrated that low extroversion was associated with stronger compliance with social distancing while low conscientiousness was associated with weaker compliance with containment measures among 715 Brazilians. Ebrahimi et al. (2020) found that low extroversion and high conscientiousness were positively associated with voluntary social distancing among 4158 Norwegians. One study conducted with 8548 Japanese participants reported that compliance was positively associated with agreeableness, conscientiousness, and openness, while negatively associated with extroversion (Nofal et al., 2020). In general, extroversion showed a negative association with compliance with containment measures while conscientiousness, agreeableness, and openness showed a positive association. These findings are consistent with the aforementioned associations between personality traits and compliance in general reported in the previous studies conducted before the pandemic.

However, limitations in the previous studies warrant further research. First, they recruited a relatively small size of participants within one country. Given the pandemic has widely affected countries on the globe, it is necessary to examine a large-scale dataset for better generalization. Second, related to the analysis method, use of frequentist ANOVA or regression analysis cannot inform us which regression model is the best model to explain compliance among all possible models (Han & Dawson, 2021). The previous studies entered trait scores into their analysis model and examined their significant with *p*-values. However, $p < .05$ is only about a null hypothesis, not an alternative hypothesis (Han et al., 2018). Also, testing the regression model with multiple trait scores entered does not inform us whether the tested model is the best model; instead, the model is only being compared with a null model (Han & Dawson, 2021).

To address the issues, a large-scale international survey dataset, COVIDiSTRESS Global Survey dataset (Yamada et al., 2021), was analyzed with Bayesian generalized linear model (GLM). The best model explaining compliance with Big Five trait scores among international participants was examined from Bayesian perspective that enables exploration the best model in a data-driven manner. It allows us to explore which model is the best model among all possible candidate in terms of all possible combinations of candidate predictors (Wagenmakers et al., 2018). Also, the best model identified by Bayesian method is more stringent than the ordinary regression model in frequentist analysis. Consequently, the identified model is less likely to commit overfitting caused by an unnecessarily complicated model (Han & Dawson, 2021). Bayesian GLM was employed in this study given these methodological merits.

## 2. Methods

All data and *R* source code files for the present study are available via the Open Science Framework project page at https://osf.io/5jgbu/.

### 2.1. Dataset

In this study, a large-scale international dataset, COVIDiSTRESS Global Survey dataset (Yamada et al., in press), was analyzed. This dataset was initially collected from 173,426 participants across 179 countries. The project was conducted to examine the relationship between participants' psychological and behavioral responses to COVID-19. The cleaned data file available for public (https://osf.io/f8h9w/) contained responses from 125,306 participants across 177 countries (see Lieberoth et al. (2021) and Yamada et al. (2021) for demographics and cleaning procedures). After performing pre-process procedures (described in supplementary methods), responses from 61,889 participants across 19 countries were used for further analyses. Tables S1 and S2 present demographical information of the whole dataset and samples in each, respectively.

### 2.2. Measures

The full survey form used for COVIDiSTRESS Global Survey is available at https://osf.io/mhszp/. It has been translated into different languages by international collaborators who participated in the project.

#### 2.2.1. Big Five Inventory

To measure participants' personality traits, the Short 15-item Big Five Inventory (BFI-S) with 15 items was used (Lang et al., 2011). Each subscale in Big Five traits, neuroticism, extroversion, openness, agreeableness, and conscientiousness, was measured with three items. Responses were anchored to a six-point Likert scale ("Strongly disagree"—"Strongly agree").

#### 2.2.2. Compliance with preventive measures

In this study, three items about compliance were employed to measure three dependent variables. For general compliance with preventive measures, "I have done everything I could possibly do as an individual to reduce the spread of Coronavirus" was presented. To assess compliance with distancing, "I have done everything I could possibly do to keep physical distance to others" was used. These items were selected as they were directly related to one's tendency to abide by prevented measures. In addition to the first item about general compliance, the second item about distancing was included because distancing measures were found to be particularly influential on people's economic status and wellbeing (Tull et al., 2020).

In addition, "I feel that keeping a physical distance from others would have a high personal cost to me," was employed to assess the perceived personal cost to abide by distancing measures. Responses were anchored to a six-point Likert scale ("Strongly disagree"—"Strongly agree"). The item about the perceived cost was included in the analyses for additional evidence on behavioral tendency. In fact, previous research about how people behave when they are presented with guidelines for desirable actions (e.g., Han et al., 2017) suggests why such an item can provide additional evidence. The perceived cost and difficulty to follow such guidelines better predicted actual behavioral outcomes compared with self-reported intent to follow the guidelines (Han et al., 2017). Given intent to comply with guidelines asked by explicit questions is likely to be susceptible to social desirability bias particularly during the pandemic (Daoust et al., 2020), use of an item inquiring about the perceived cost would provide a better proxy for actual behavioral tendency as shown in the prior research.

Although a total of six items were employed to assess compliance in the original COVIDiSTRESS Global Survey, only three items were analyzed in the present study. The other three items were excluded from the analyses because they were deemed to be irrelevant to the main focus of the present study, one's own compliance. The first excluded item was more about one's knowledge about preventive measures instead of behavior ("I feel well informed about steps I can take, to help reduce the spread of Coronavirus"). The second excluded item asked whether one felt that other people were following measures well ("I trust others around me to follow guidelines to stop the spread of Coronavirus"). The third excluded item was primarily about one's preparedness for quarantine and isolation instead of compliance ("I have bought large extra supplies of food or grocery items").

#### 2.2.3. Demographical information

Following a previous study that examined COVIDiSTRESS Global Survey dataset (Lieberoth et al., 2021), three demographics variables, participant' age, gender, and educational level, were employed as covariates. These variables were also employed in the previous studies examining compliance and beliefs on preventive measures (Alper et al., 2020; Daoust, 2020; Lüdecke & von dem Knesebeck, 2020). The studies reported that the aforementioned demographical factors were significantly associated with behavioral and psychological responses to preventive measures, such as protective behavior, distancing, and COVID-19 conspiracy theories. Given the findings from the previous studies, the three demographical variables were employed as covariates in the present study as were in Lieberoth et al. (2021).

### 2.3. Analysis plan

The dataset was first preprocessed to exclude inappropriate responses and outliers. Then, the reliability and validity of the BFI-S were tested. Measurement alignment was also performed to enable appropriate analyses of the multi-country dataset. Further details about the procedures are described in supplementary methods. After completing measurement alignment, correlation analysis was performed to examine the correlations between the Big Five personality traits and compliance variables.

Bayesian GLM implemented in *BayesFactor* package was performed with adjusted BFI-S factor scores to explore the best model for each of three dependent variables. Five adjusted BFI-S subscale scores were entered as predictors, participants' age, gender, and educational level as covariates, and their country as a random effect. Frequentist and Bayesian GLM with *lmerTest* and *brms* packages were conducted with the identified best model reporting the greatest Bayes factor (BF) (vs. null model) to estimate the coefficient, *p*-value, and BF (vs. null hypothesis) of each predictor. For *brms*, the default Cauchy prior, Cauchy (0, 1) (Rouder & Morey, 2012).

BF indicates to what extent observed data supports a specific model over another. If two models, Models A vs. B, are compared, $BF_{AB}$ means to what extent evidence favors Model A over B (Wagenmakers et al., 2018). $BF_{AB} \geq 3$, which is a widely used cutoff, suggests that evidence positively supports Model A over B (Han, 2020). In this study, BF was calculated for each candidate model in terms of BF against the null model only with intercepts. A model reporting the greatest BF in Bayesian GLM was identified as the best model. Similarly, for each estimated coefficient (e.g., $B$), BF indicating to what extent data supports an alternative hypothesis, $B \neq 0$, was also calculated with *brms* (threshold: $BF \geq 3$).

Because there have been concerns regarding whether excluding outliers significantly alters analysis results (Aguinis et al., 2013), Bayesian GLM was performed once again with the dataset that was not screened for outliers. The results from Bayesian GLM with the dataset with outliers were compared with those from Bayesian GLM with the dataset without outliers.

## 3. Results

### 3.1. Descriptive statistics

Table S3 presents descriptive statistics, including mean and standard deviations values for the whole dataset and each country, of each predictor and dependent. Correlations between the Big Five personality trait and compliance variables are reported in Table S4. In supplementary materials, the correlation between two compliance items, which demonstrated a large effect, $r = 0.65$, was discussed in "About compliance items" section.

### 3.2. Reliability and validity check, and measurement alignment

Cronbach αs of the BFI-S were reported in Table S3. After excluding data from 29 countries with $\alpha < 0.55$, data from 19 countries were used for further analyses ($N = 61{,}889$). The whole sample α values were at least 0.60 in all five subscales.

When measurement invariance was tested, even configural invariance without any model constraints was not achieved, RMSEA = 0.072, SRMR = 0.056, CFI = 0.811, TLI = 0.752. Thus, measurement alignment was performed to adjust factor loadings for further analyses. Resultant $R^2$ values demonstrated that for all five subscales, non-invariance was well absorbed during alignment, $R^2 > 0.95$ (see Table S5).

### 3.3. Bayesian GLM

The result of model comparison with Bayesian GLM is presented in Table S6. Table 1 presents the result of frequentist and Bayesian GLM for each dependent variable with estimated coefficients. First, when general compliance tendency was examined, the model with all five subscale scores reported the greatest BF, 6.87e+2364. All subscales, except extroversion, were positively associated with the dependent variable. All estimated coefficients were significantly different from zero.

Second, when compliance with distancing was a dependent variable, the model with all five subscale scores was identified as the best model, BF = 1.82e+2487. All subscales, except extroversion, showed positive association. All estimated coefficients significantly differ from zero.

Third, when perceived personal cost to comply with distancing was tested, the model without openness showed the greatest BF, 2.08e+1022. All included predictors (i.e., neuroticism, extroversion, agreeableness) except conscientiousness were positively associated with the perceived personal cost. All estimated coefficients were significantly different from zero.

When these results were compared with the results from Bayesian GLM with the dataset containing outliers, there were no significant differences in the identified best models. The three identified best models were identical across the two different conditions. Further details are described in "Whether outlier exclusion based on Mahalanobis distance significantly influenced Bayesian GLM outcomes" section in supplementary materials.

## 4. Discussion

In this study, the best regression models explaining three different types of compliance with measures to contain COVID-19 were identified by Bayesian GLM with a large-scale international dataset. Compliance with preventive measures was positively associated with all Big Five traits except extroversion that showed negative association. These results are consistent with previous studies that examined the relationship between Big Five traits and compliance during the pandemic with relatively small-scale datasets. Extrovert people might experience more difficulties with distancing measures because they strongly prefer social activities (Nofal et al., 2020). Neuroticism is perhaps associated with increased concern of being contracted COVID-19 so with compliance (Qian & Yahara, 2020). Agreeable, open-minded, and conscientious people might comply with the measures perhaps because they tend to value communal goals and harmony (agreeable), be more opened to the new social norms (open-minded) and adhere to regulations and rules consistently (conscientious) (Abdelrahman, 2020; Nofal et al., 2020; Zajenkowski et al., 2020).

Interestingly, the perceived personal cost to comply with preventive measures, which has not been well examined in the previous studies, were positively associated with neuroticism, extroversion, and agreeableness while only negatively associated with conscientiousness. It is well expected to see the positive association with extroversion and negative association with conscientiousness because extroverted people might experience more difficulties to be isolated from others while

**Table 1**
Frequentist and Bayesian GLM results with the best model for each dependent variable.

| | B | SE | β | Standardized SE | df | t | p | Bayes factor (vs. B = 0) |
|---|---|---|---|---|---|---|---|---|
| DV: "I have done everything I could possibly do as an individual to reduce the spread of Coronavirus" (overall compliance) | | | | | | | | |
| Neuroticism | 0.01 | 0.00 | 0.03 | 0.00 | 61,220.00 | 5.75 | <.001 | Infinite |
| Extroversion | −0.01 | 0.00 | −0.03 | 0.00 | 61,490.00 | −6.23 | <.001 | Infinite |
| Openness | 0.03 | 0.00 | 0.10 | 0.00 | 61,470.00 | 23.88 | <.001 | Infinite |
| Agreeableness | 0.04 | 0.00 | 0.12 | 0.00 | 61,450.00 | 28.67 | <.001 | Infinite |
| Conscientiousness | 0.05 | 0.00 | 0.17 | 0.00 | 60,590.00 | 34.32 | <.001 | Infinite |
| DV: "I have done everything I could possibly do to keep physical distance to others" (compliance with distancing) | | | | | | | | |
| Neuroticism | 0.01 | 0.00 | 0.03 | 0.00 | 61,380.00 | 7.58 | <.001 | Infinite |
| Extroversion | −0.01 | 0.00 | −0.05 | 0.00 | 61,490.00 | −11.98 | <.001 | Infinite |
| Openness | 0.04 | 0.00 | 0.10 | 0.00 | 61,490.00 | 24.01 | <.001 | Infinite |
| Agreeableness | 0.03 | 0.00 | 0.09 | 0.00 | 61,480.00 | 22.51 | <.001 | Infinite |
| Conscientiousness | 0.04 | 0.00 | 0.12 | 0.00 | 61,080.00 | 25.35 | <.001 | Infinite |
| DV:"I feel that keeping a physical distance from others would have a high personal cost to me" (perceived personal cost of distancing) | | | | | | | | |
| Neuroticism | 0.06 | 0.00 | 0.16 | 0.00 | 61,100.00 | 33.86 | <.001 | Infinite |
| Extroversion | 0.07 | 0.00 | 0.20 | 0.00 | 61,480.00 | 45.82 | <.001 | Infinite |
| Agreeableness | 0.01 | 0.00 | 0.02 | 0.00 | 61,420.00 | 4.85 | <.001 | Infinite |
| Conscientiousness | −0.01 | 0.00 | −0.02 | 0.00 | 60,200.00 | −4.51 | <.001 | Infinite |

Note. Only BFI-S predictors of interest were included. Full results with covariates are presented in Table S7.

conscientious people might perceive doing so is consistent with their own personality (Carvalho et al., 2020; Liu et al., 2021; Nofal et al., 2020). In general, these findings are consistent with the previous studies that examined the associations between Big Five personality traits, risk aversion and prosocial tendency, and compliance.

Then, why were neuroticism and agreeableness positively associated with the perceived cost while also being positively associated with compliance? People with high neuroticism scores might comply preventive measures due to their strong concerns over COVID-19, but the strong concern would also make them feel more negative about their behavior (Liu et al., 2021). In fact, the negative impact of neuroticism on mental health during the pandemic period has been reported (Qian & Yahara, 2020). Agreeable people might also experience negative sentiments perhaps because they tend to emphasize with and help others in so they might be uncomfortable with being separated with social interactions with such others (Abdelrahman, 2020; Graziano et al., 2007).

We can also consider the association between conscientiousness, morality, and virtue. Previous studies suggested that conscientious traits are significantly associated with morality and virtue (Kalshoven et al., 2011; Roberts et al., 2014). Moral philosophers have argued that virtuous people do not feel that moral actions are burdensome because they have internalized and habituated morality and virtue into themselves (Han, 2015; Sanderse, 2014). So, conscientious people may be less likely to feel that complying preventive measures, particularly social distancing, are very demanding to do in their everyday lives. On the other hand, although agreeableness and openness are positively associated with prosocial tendency (Carlo et al., 2005; Kline et al., 2019), they are not deemed to be associated with morality or virtue (Kalshoven et al., 2011; Roberts et al., 2014). Perhaps people possessing prosocial motivation do not necessarily be conscientious or virtuous. In the cases of such people, prosocial motivation might originate from sources external from themselves, such as social norms, conventions, or relationships (Choi et al., 2020), instead of internalized morality and virtue possessed by virtuous people. Hence, people who are not conscientious might experience more difficulties and struggles while complying with preventive measures compared with conscientious people.

One interesting point is that openness, which is positively associated with prosociality similar to agreeableness (Kline et al., 2019), was not significantly negatively associated with the perceived personal cost of compliance. It might be explained by a negative association between openness and (right-wing) authoritarianism perspective (Hodson et al., 2009; Manson, 2020). Hodson et al. (2009) reported that within the context of intergroup threat, only openness among the Big Five personality traits negatively predicted right-wing authoritarianism perspective, which was significantly associated with perceived intergroup threat and prejudice. This finding may suggest that compared with agreeableness, openness is more likely to work as a buffering factor while coping with hostile external situations. In fact, Manson (2020) showed that extreme right-wing authoritarianism negatively predicted willingness to comply with distancing measures during the pandemic. Hence, it would be possible to say that openness would positively predict one's willingness to follow distancing measures, and finally, did not show a significant positive association with the perceived cost.

Findings from the present study will be able to provide useful theoretical insights about research on the relationship between personality traits and compliance. First, in the present study, large-scale data collected from diverse countries were analyzed. The majority of previous studies that examined the aforementioned relationship were conducted with relatively small-scale data collected from a single country. Thus, the present study contributes to the generalization of the theory across different countries and cultural backgrounds. Second, a relatively less studied aspect, the perceived personal cost of compliance, was examined. Given the perceived cost and difficulty well predicts actual behavioral tendency to follow guidelines and is robust against social desirability bias (Han et al., 2017), the analysis of the perceived cost in the present study would provide additional evidence regarding the relationship between personality traits and complying behavioral tendency.

Moreover, one methodological contribution of the present study is that it employed Bayesian GLM to explore the large-scale international dataset. By utilizing the data-driven method, it was possible to explore the regression models that best predicted compliance-related variables with the least model complexity with big data. Given these, findings from the present study will provide useful insights to researchers who are interested in the relationship between compliance with measured to contain COVID-19 and various personality traits.

However, several limitations warrant further research. First, although one item inquired about participants' compliance tendency in an indirect way, the two other items explicitly inquired about compliance behavior. The two items might not be ideal to assess participants' actual compliance behavior due to possible social desirability bias. Thus, future studies may need to employ more direct measures for compliance behavior other than self-report to better examine actual behavior. Second, the BFI-S instead of its full version was used, so it might result in limited measurement reliability and validity. In fact, Hahn et al. (2012) reported that the reliability of the BFI-S was inferior to that of a longer measure, such as the NEO-PI-R. Hence, it would be possible to consider employing a longer measure to examine personality traits in a more reliable way.

## CRediT authorship contribution statement

**Hyemin Han:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

Hyemin Han has no known conflict of interest to disclose.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2021.110787.

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