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# The blind spot: Studying the association between survey non-response and adherence to COVID-19 governmental regulations in a population-based German web-survey

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Currently, a multitude of research deals with adherence to COVID-19 regulations. Although selective non-response might question the validity of generalising research findings, the issue has, as yet, received only little attention. Presumably, choosing to participate in a COVID-19 study is based on a similar decision-making process as that concerning adherence to COVID-19 regulations. Certain characteristics might predict both outcomes which would result in overestimated mean levels and a biased predictor structure of adherence to COVID-19 regulations. We used a random sample of adolescents (born 2001–2003) from the German family panel study *pairfam* who were first interviewed (face-to-face) in winter 2018/19 and were invited to participate in a (web-based) follow-up COVID-19-interview in spring 2020. Using a simple weighting procedure and Heckman selection models, we found an overestimated mean of adherence to COVID-19 regulations, with the association with gender being overestimated and that with education and migration background underestimated. Other than expected, the extent of bias was less severe and fewer variables were affected. We suggest including a set of additional variables into the models estimating adherence to tackle the bias in the predictor structure and to address mean level bias by using weights accounting for population characteristics. Although COVID-19 studies indeed appear to provide biased results, being able to reduce this bias is generally good news for high-quality COVID-19 studies.

*Keywords:* COVID-19; nonresponse bias; unit nonresponse; Heckman selection; rule compliance

## 1 Introduction

In pandemic situations and in the current COVID-19 pandemic in particular, compliance with governmental health regulations is crucial to slow down the spread of disease and reduce the number of critical cases with high risk of mortality. Accordingly, compliance with COVID-19 government measures is currently of great political and scientific interest. A multitude of public opinions and survey results are currently being published (see for instance De Man, Campbell, Tabana, & Wouters, 2021) that provide insights not only into overall compliance with various regulations but also into which population subgroups are least/most compliant. However, it remains open as to whether these studies provide unbiased results.

Random sampling is an important condition in being able to generalise findings but in itself is not sufficient (for COVID-19: Bethlehem, 2015; Post, Class, & Kohler, 2020; Schaurer & Weiß, 2020). The second condition refers to unit nonresponse. There are varying reasons why not all randomly selected individuals participate in a survey. Survey nonresponse is unproblematic as long as these reasons are unrelated to the study subject (missing completely at random, Little & Rubin, 2002; Rubin, 1976). If, however, they are related to the subject of interest but ignored, the information provided by the study sample might deliver biased insights for the study population; hence, the results would not be generalisable (e.g. Bethlehem, 2015; Cornesse et al., 2020; Groves, 2006; Kohler, Kreuter, & Stuart, 2019; Peytchev, 2013).

In the current paper, we focus on nonresponse in the context of surveys investigating COVID-19 regulations. We argue that both participating in a survey and adhering to COVID-19 regulations can be understood as "compliant behaviour"—that is, compliance with particular requests for action. In the words of Cialdini and Goldstein (2004), "[c]ompliance refers to a particular kind of response-acquiescence to a particular kind of communication—a request."

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Accordingly, both requests could instead also be rejected and answered with non-compliance or nonresponse. Thus, individuals' reactions—whether or not they comply—necessarily involve evaluations. We argue that due to a similar structure of the requests, the psycho-social decision-making processes for survey response and adherence to COVID-19 regulations may resemble one another, and, therefore, a large number of particular person-specific characteristics could predict compliance with both requests (see also "common cause" at Post et al. (2020), or "confounders" at Schaurer and Weiß (2020), for similar argumentations). Systematic survey nonresponse would, consequently, lead to an over-representation of individuals following the COVID-19 regulations as well as a blind spot in the most interesting group of the population for COVID-19 studies: the non-compliant. Further, this would result in positively biased mean levels of compliance with COVID-19 regulations and biased associations with individual characteristics.

The current paper has three goals:

1. To conceptualise the similarity in the *request* for survey participation and compliance with COVID-19 regulations and to identify relevant common predictors for *acquiescence* to these requests.

2. To analyse the extent and direction of the bias in adherence to COVID-19 regulations due to survey nonresponse—both regarding the sample mean and individual predictors.

3. To formulate recommendations on how to treat this nonresponse bias in future research.

The analysis of survey nonresponse and adherence to COVID-19 regulations is based on a random sample of young adults (born 2001–2003) who were interviewed for the first time in winter 2018/19 (face-to-face) as part of a new sub-sample of the German family panel study *(pairfam)* and who were asked to participate in a special COVID-19 web-survey in the spring of 2020. A previous study investigated personality-related nonresponse bias in the prediction of compliance with COVID-19 regulations based on a German online survey (Schaurer & Weiß, 2020). The authors argue that the extent of the bias cannot be assessed because COVID-19 related behaviour can only be observed for respondents but not the non-respondents. While they find that some personality traits are related to both participation and COVID-19 related behaviour, we take the analysis a step further by including a larger range of potentially relevant common predictors and *approximate* the extent of the bias using Heckman selection models.

## 2 Survey nonresponse and adherence to COVID-19 regulations

### 2.1 Common structure

To underline our assumption that survey participation and compliance with COVID-19 regulations might be associated, we first compare the *structure of both requests*. We apply the framework of the survey participation research by using the overview work of Groves, Cialdini, and Couper (1992) to identify typical characteristics of survey design and apply them to requests for compliance with COVID-19 regulations. Generally, in comparison to other fields of social science research, both concepts have in common that an external institution makes an explicit request for action that needs direct response: either participation in or rejection of this request. Moreover, both requests are communicated in a way to avoid non-compliance. This holds in particular for COVID-19 regulations, which are obligatory (albeit in most countries with a low level of sanctioning), while the request for survey participation is (with few exceptions) less pressing. Generally, the benefits to follow either of the requests are conveyed by an external institution and are abstract, thus requiring a certain degree of acknowledgement of science: Survey participation contributes to scientific progress, while trust in science is necessary to understand the benefit of the COVID-19 regulations for one's own health and that of others. Therefore, to increase trust in the requests, the responsible scientific institutions are highlighted as conductors or consultants, often in collaboration with government institutions.

Still, the structures of the two requests differ in some aspects: First, survey participation is most often a one-time request with a clearly defined task (i.e., answering questions) to be completed in a defined period of time. In contrast, COVID-19 regulations allow for more personal margins in their responses and affect daily lives over a course of several months (and potentially longer). Second, the contact with a potential respondent is often established first through a personal letter with information about the study and the responsible institutions followed by either personal contacts through interviewers (CAPI, CATI) or guidance to a self-administered interview (PAPI, web-survey). In contrast, the communication of COVID-19 regulations is generally directed towards all inhabitants of an area (most often countries) via press or social media.

Despite these differences we argue that the structures of both requests bear similarities that could influence individuals' decision-making processes to comply with such requests in an analogous manner.

### 2.2 Common characteristics

Both constructs are often theoretically analysed using a rational choice argumentation in which individual action is based on a positive evaluation of cost and benefits. In *survey*

*participation research*, rather than one uniform theory, a variety of theoretical frameworks have been applied to explain why individuals differ in their likelihood to participate in social surveys (see for instance Keusch, 2015). Very prominently, cost-benefit approaches[1] are integrated into many of these theories: Individuals are more likely to comply with a survey request if the anticipated benefits exceed the anticipated costs. For instance, according to social exchange theory (Dillman, 1978), social interactions, including participation in a survey, create certain (opportunity) costs (i.e., time use, cognitive effort) and benefits/rewards (i.e., appreciation, incentives). Naturally, individuals might differ in their evaluation of these benefits and costs. The leverage-salience theory (Groves, Singer, & Corning, 2000) further clarifies which and how certain characteristics shape these evaluations. For example, survey participation is more likely if survey characteristics that are of interest to the respondent, such as the topic, are made salient, that is prominent, upon request.

The most prominent approach for understanding *compliance with COVID-19 regulation*, the Health Belief Model, is often applied (Champion & Skinner, 2002; Rosenstock, 1974). This model is rational-choice-based, too, using individual beliefs about the threat of the disease and the effectiveness of a promoted measure to predict compliant behaviour with these measures. Similarly, a set of individual characteristics might affect the perceptions of the health threat and of the protective behaviour (Champion & Skinner, 2002; Rogers, 1975). While the severeness of consequences for the two requests are quite different by nature, we are interested in whether certain characteristics are associated with the same *direction* of the outcome (compliance vs non-compliance), meaning that the associations do not have to be equally strong.

Previous research also points to many *similarities in the characteristics of individuals* complying with the requests. The socio-demographic, context, and personality characteristics of survey respondents have been seen to resemble those of individuals who abide by COVID-19 regulations. Regarding the *socio-demographic characteristics* of a sample person, typically being female, highly educated, employed, as well as living with a partner and children and having no migration background is predictive of survey participation (e.g. Haunberger, 2011; Müller & Castiglioni, 2015a; Richter, Körtner, & Saßenroth, 2014; Vercruyssen, Wuyts, & Loosveldt, 2017). The reasons are various: While education and employment are assumingly associated with a higher affinity to science and, hence, increased chances of participation, having a larger family and being a stay-at-home mother increase the number of potential sample persons. With higher age, individuals were shown to be more compliant (e.g. Haunberger, 2011) while the association might be non-linear (Daoust, 2020).

Regarding *context characteristics*, people living in the Eastern part of Germany compared to the Western part in cities and in more deprived areas have been shown to participate less often.

We would expect to see similar characteristics among individuals adhering to COVID-19 regulations as those participating in a survey. One might suppose that higher education would be positively related to acknowledgement of scientific information and, hence, to compliance with COVID-19 regulations. Larger household size might decrease the need for external contacts and might increase the sensitivity towards risky behaviour because of close contact to several other individuals. Findings from previous studies on adherence to COVID-19 regulations are in line with most of our assumptions. Large household size, being of higher age (60+), being female, and having a migration background have been found to increase compliance with the regulations (e.g. Brouard, Vasilopoulos, & Becher, 2020; Pollak, Shoham, Dayan, Seri, & Berger, 2022; Qeadan et al., 2020). Findings on the association of educational level and regulation compliance have, however, been less congruent. While some have found compliance to be associated with a higher level of education (e.g. Pollak et al., 2022; Qeadan et al., 2020), others have found it to be associated with a lower level (e.g. Nivette et al., 2021). A lack of association has even been reported as well (Brouard et al., 2020).

Studies have shown that *context characteristics* matter for the level of adherence to COVID-19 regulations (Wright, Sonin, Driscoll, & Wilson, 2020). For instance, people living in areas with higher levels of poverty have been shown to be less adherent (Wright et al., 2020). As economic context conditions matter, we use East as opposed to West Germany, and city versus rural life as structural indicators. To our knowledge, no studies on adherence to COVID-19 regulations have as yet examined differences between the two former German parts and rural vs urban areas.

Several *personal and personality-related characteristics* have been shown to be associated with survey participation and/or compliance with COVID-19 regulations. Regarding survey participation, people who are physically and mentally healthier, exhibit higher levels of general trust, experience fewer behavioural difficulties and conduct problems,

[1] A different approach towards explaining compliance with a survey request are heuristics: Arguably, the decision process for or against survey participation might not be an active process as assumed above but rather follow cognitive short-cuts, in particular if the time to evaluate the decision is limited. Several principals of such compliance heuristics have been identified, such as social proof (Festinger, 1954) or authority (Cialdini & Goldstein, 2004). Rather than evaluating the pros and cons of survey participation on an objective basis, individuals are likely to follow the behaviour of others (in particular if they are similar to themselves like friends and family) or positively react to a request if formulated by authorities. Also, those arguments could be implemented in theories of health behaviour.

and have lower levels of hyperactivity or peer problems but more prosocial behaviour have been shown to be more likely to participate in surveys (e.g. Cheung, ten Klooster, Smit, de Vries, & Pieterse, 2017; Lynch, 2003). Also, regarding the Big-Five personality traits, more conscientious, agreeable and open individuals have been seen to participate more often (Cheng, Zamarro, & Orriens, 2020; Lugtig, 2014; Richter et al., 2014). On the other hand, dimensions of the Dark Triad personality traits (Paulhus & Williams, 2002), such as Machiavellianism and narcissism, have been associated with reduced chances of participation.

Most of the *personal and personality characteristics* presumably relate to adherence to COVID-19 regulations in a similar way, mostly by distinguishing people who show compliant behaviour to a request with unclearly foreseeable benefits. For instance, trust in general and in government institutions, in particular, has been shown to be associated with adherence to COVID-19 regulations (Nivette et al., 2021), however, trust in science and trust in the US president D. Trump have not shown an additional positive association (Brouard et al., 2020). While behavioural problems related to difficulties in social situations seem to promote adherent behaviour, conduct problems, hyperactivity and having problems to find friends have been shown to hamper such behaviour following COVID-19 governmental guidelines (e.g. Blagov, 2021, 5; Miguel, Machado, Pianowski, & Carvalho, 2021; Nivette et al., 2021; Pollak et al., 2022). Also, lower levels of agreeableness and some aspects of the Dark Triad have been related to lower levels of regulations adherence (e.g. Blagov, 2021, 5; Laun & Wallenius, 2015; Nowak et al., 2020). However, regarding physical conditions and mental health, the association might be the opposite of survey participation: Presumably those who are at higher risk of a severe course of the disease and those whose mental health is already strained might refrain from risky behaviour and, accordingly, follow COVID-19 regulations more strictly (Qeadan et al., 2020). In addition, in a COVID-19 related online survey analysed by Schaurer and Weiß (2020), individuals who considered themselves as generally trusting or lazy were not only shown to be overrepresented in the survey but to be more and less likely to comply with risk minimizing behaviours.

## 3 Data and Method

### 3.1 Data

Our analysis is based on data from the German Family Panel study (pairfam), release 11.0 (Brüderl et al., 2020) and the pairfam COVID-19 survey (Walper et al., 2020). Huinink et al. (2011) provide a detailed description of the main study. The initial random sample of respondents consists of individuals living in Germany born in three different cohorts: 1991–1993, 1981–1983, and 1971–1973. The 11$^{th}$ wave of pairfam was conducted between September 2018 and April 2019 and included a new sub-sample of individuals born between 2001 and 2003. In November 2019, the field period for the 12$^{th}$ wave began, which had to be prolonged until July 2020 because the spread of the virus forced a mode change from a face-to-face to CATI survey (Gummer et al., 2020). In April 2020, shortly after the first lock-down in Germany had been relaxed and overlapping the field period of Wave 12, all current pairfam respondents received a letter inviting them to participate in a special web-based COVID-19 survey (Walper et al., 2020). This survey aimed to collect a wide range of information on life in a pandemic with a focus on family and social relations. In a special module for the youngest cohort only, questions regarding compliance with COVID-19 regulations were assessed. These respondents were aged 16–20 at the time of the COVID-19 study.

We used the first observation (Wave 11) of the 2001–2003 born cohort as reference point ($N = 2,472$). During this interview, a wide range of information on the respondents was collected. While this interview was framed as a scientific study focussing on family and intimate social relations and was conducted using face-to-interviews, the COVID-19 follow-up study highlighted life in times of SARS-CoV-2 as a main topic and was conducted as a web-based survey ($N = 851$). Although the first measurement occasion might already be affected by cross-sectional selectivity, we assumed that this selectivity is more strongly related to the topic of family (and not health) and to face-to-face contact (and less to digital accessibility) than a web-based COVID-19 study. Accordingly, we used the initial sample as benchmark sample from which we derived information about the respondents; but more importantly the non-respondents of the COVID-19 study.

### 3.2 Analytical strategy

First, we examined *patterns of nonresponse* in the COVID-19 follow-up survey with a probit model. We investigated which variables were predictive of participation.

Second, we analysed the *bias in the mean levels* of compliance with COVID-19 regulations. To this end, based on the model from the first step, we created survey weights using the inverse inclusion probability with different sets of predictors. The different sets helped to clarify whether basic sociodemographic and context information (usually available in any study) were sufficient to tackle the nonresponse bias or whether more specific personal and personality-related information (these need to be assessed explicitly) were necessary. The constructed weights were applied to correct the mean levels of compliance with COVID-19 regulations.

Third, we assessed the extent of *bias in the predictors* of adherence to COVID-19 regulations. Therefore, we applied Heckman selection models (Bushway, Johnson, & Slocum, 2007; Heckman, 1976; Vella, 1998; Wooldridge, 2015, chap. 17.5). In these, a probit model for predicting survey par-

ticipation was estimated, on the basis of which a correction factor—the inverse Mills ratio $\lambda$—was built. This correction factor was included in a simultaneously estimated OLS regression model which predicted compliance with COVID-19 regulations. This model then accounted for potentially selective survey nonresponse. After that, we estimated uncorrected OLS regression models without accounting for survey nonresponse and compared these uncorrected estimators with the corrected estimators from the Heckman models using seemingly unrelated estimates with $\chi^2$-testing. All data handling was conducted using Stata 16 and Figure 1 and 2 were created with the Stata ado *coefplots* (Jann, 2014).

### 3.3 Measures

Two dependent variables were examined: First, survey nonresponse indicated whether or not a respondent from the pairfam baseline sample participated in the COVID-19 follow-up study (0=no, 1=yes). For descriptive information see Table 1. Second, compliance with COVID-19 regulations was measured through the frequency (1: never to 5: very often) of three different social distancing facets, indicating shelter-in-place regulations ("I met up with people outside my household, even when it was not necessary."), protecting vulnerable groups ("I visited or was visited by older relatives or friends (age > 65)") and social distancing behaviour in social situations ("I was not particularly vigilant about maintaining 1-2 meters between myself and people outside my household."). For the ease of interpretation, we built a reverse-coded z-standardised sum score out of all three items with higher levels indicating stronger compliance (with a mean of zero and a standard deviation of 1).

All independent variables were collected at baseline, that is the first wave of observation of the new sub-sample (born 2001–2003, pairfam Wave 11). For a summary see Table 1 and, for more detailed information see the documentation (Thönnissen, Wilhelm, Alt, Reim, & Walper, 2020). *Sociodemographic* indicators included were being female, being single, and having a migration background (1st or 2nd generation) (all: no/yes). To account for heterogeneity in the age range, we distinguished two equal-sized age groups (15–16 vs 17–18 years at baseline). Education was categorised into being currently enrolled in a high education track, lower education track (reference category), in vocational training or following other education paths. *Context* variables encompassed living in an urban area (compared to 0: rural), living in the Eastern part of Germany (no/yes) and a measure for household deprivation (based on a 3-item scale on whether or not the household has sufficient financial resources). *Personal* resources were measured via physical health (physical component of the SF12-scale), trust (2 items on general trust regarding other people), and depressive symptoms ("State-Trait-Depression Scales" (STDS Form Y-2)). Having conduct problems (e.g., stealing, lying, losing temper), showing hyperactivity (e.g., being unconcentrated, easily distracted), having peer problems (e.g., mobbing, having no friends, being alone) and showing pro-social behaviour (e.g., being nice, helpful, sharing) all stem from the Strengths and Difficulties Questionnaire (SDQ). *Personality* characteristics were indicated by five traits of the Big Five Inventory (BFI-K; neuroticism, extraversion, agreeableness, conscientiousness, openness) and two traits of the Dark Triad (Machiavellianism (manipulating, lying, using flattery) and narcissism (mean of the two dimensions rivalry and admiration). Psychopathy was not included due to very high correlations with Machiavellianism. Finally, a number of *interview characteristics,* mostly pertaining to the face-to-face baseline interview, were additionally included. (Previous) interview experiences were shown to be associated with (re-)participation in (panel) studies (Lepkowski & Couper, 2002; Müller & Castiglioni, 2015b, based on pairfam data). We did not expect the interview characteristics to be associated with compliance with COVID-19 behaviour, so these variables were only included in the models predicting survey participation—in particular in the selection part of the Heckman models to improve the correction factor. We included the number of contacts prior to the interview (indicating the difficulty to reach the respondent), whether or not the gender of the interviewer was opposite to that of respondent, age (+age$^2$) of the interviewer, interview duration (per 10 min, +duration$^2$), household size (+size$^2$), percent of missing item responses (logarithmized), participation in Wave 12 interview (indicating general willingness to participate in a study), whether the partner answered the partner questionnaire in Wave 11, and whether the respondent was cohabitating with their parents. As shown in Table 2, for some variables a small number of missing values was found which we substituted with mean values. In a robustness check comparing the final models with models based on list-wise deleted data, no major differences were found (see Online appendix).

## 4 Results

### 4.1 Survey nonresponse in the COVID-19 study

To examine patterns of *survey nonresponse*, we predicted the probability that a respondent participated in the COVID-19 survey using probit models with characteristics derived from the baseline interview. The results are displayed as average marginal effects (AMEs, see Figure1). As regards *interview characteristics*, we found that with each additional attempt to contact the respondent in Wave 11 (baseline interview), the chance for participation became one percentage point (p.p.) lower (AME = $-0.01$, $p < 0.01$). If the respondent had already participated in the regular Wave 12 or if their partner had answered the partner questionnaire in Wave 11, they had a 30.4 percentage point (13.1 p.p., respectively) higher chance of participating. Regarding *socio-*

Table 1
*Overview on all included variables*

| | | | | | | Mean levels and Standard Deviations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | | Missings | | Baseline | | COVID19 survey | | Total | | Difference |
| | Items | Min | Max | *N* | % | Mean | SD | Mean | SD | Mean | SD | *p* |
| Adherence to COVID-19 regulations, z-std. | 3 | −2.8 | 1.5 | 1621 | 66 | - | - | 0.00 | 1.00 | 0.00 | 1.00 | - |
| Survey participation | 1 | 0 | 1 | - | - | - | - | 0.34 | - | 0.48 | - | - |
| Socio-demographics | | | | | | | | | | | | |
| Women | 1 | 0 | 1 | - | - | 0.44 | - | 0.58 | - | 0.49 | - | 0.00 |
| Age 17+ | 1 | 0 | 1 | - | - | 0.46 | - | 0.41 | - | 0.44 | - | 0.02 |
| Single | 1 | 0 | 1 | - | - | 0.75 | - | 0.80 | - | 0.76 | - | 0.00 |
| Enrolled in higher education | 1 | 0 | 1 | - | - | 0.42 | - | 0.59 | - | 0.48 | - | 0.00 |
| Edu other | 1 | 0 | 1 | - | - | 0.11 | - | 0.08 | - | 0.10 | - | 0.01 |
| Enrolled in vocat training | 1 | 0 | 1 | - | - | 0.12 | - | 0.05 | - | 0.09 | - | 0.00 |
| Migration (1+2 gen.) | 1 | 0 | 1 | - | - | 0.31 | - | 0.22 | - | 0.28 | - | 0.00 |
| Context | | | | | | | | | | | | |
| Urban | 1 | 0 | 1 | - | - | 0.33 | - | 0.28 | - | 0.31 | - | 0.03 |
| East Germany | 1 | 0 | 1 | - | - | 0.17 | - | 0.16 | - | 0.16 | - | 0.46 |
| HH econ. deprivation | 3 | 1 | 5 | 48 | 2 | 1.80 | 0.97 | 1.68 | 0.90 | 1.76 | 0.95 | 0.00 |
| Personal resources | | | | | | | | | | | | |
| Physical health (SF12) | 6 | 1 | 100 | 66 | 3 | 52.68 | 7.96 | 53.32 | 8.05 | 52.90 | 8.00 | 0.06 |
| Depressive symptoms | 10 | 1 | 4 | 4 | 0 | 1.73 | 0.47 | 1.78 | 0.49 | 1.75 | 0.48 | 0.01 |
| Trust | 2 | 1 | 5 | - | - | 2.41 | 0.72 | 2.56 | 0.68 | 2.47 | 0.71 | 0.00 |
| Conduct problems | 5 | 0 | 2 | 20 | 1 | 0.37 | 0.30 | 0.33 | 0.27 | 0.36 | 0.29 | 0.00 |
| Prosocial behaviour | 5 | 0 | 2 | 20 | 1 | 1.63 | 0.34 | 1.65 | 0.33 | 1.64 | 0.33 | 0.23 |
| Hyperactivity | 5 | 0 | 2 | 27 | 1 | 0.71 | 0.42 | 0.67 | 0.43 | 0.69 | 0.42 | 0.02 |
| Peer problems | 5 | 0 | 2 | 36 | 1 | 0.50 | 0.34 | 0.52 | 0.34 | 0.51 | 0.34 | 0.41 |
| Personality | | | | | | | | | | | | |
| Neuroticism | 4 | 1 | 5 | 7 | 0 | 2.82 | 0.86 | 2.95 | 0.87 | 2.87 | 0.86 | 0.00 |
| Extraversion | 4 | 1 | 5 | 10 | 0 | 3.40 | 0.87 | 3.33 | 0.92 | 3.37 | 0.89 | 0.08 |
| Agreeableness | 4 | 1 | 5 | 9 | 0 | 3.10 | 0.77 | 3.12 | 0.80 | 3.11 | 0.78 | 0.67 |
| Conscientiousness | 4 | 1 | 5 | 6 | 0 | 3.46 | 0.70 | 3.47 | 0.74 | 3.47 | 0.71 | 0.84 |
| Openness | 5 | 1 | 5 | 8 | 0 | 3.63 | 0.75 | 3.72 | 0.72 | 3.66 | 0.74 | 0.01 |
| Machiavellianism | 3 | 1 | 5 | 16 | 1 | 1.99 | 0.82 | 1.94 | 0.80 | 1.97 | 0.82 | 0.16 |
| Narcism | 6 | 1 | 5 | 15 | 1 | 1.95 | 0.75 | 1.88 | 0.70 | 1.92 | 0.73 | 0.03 |

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| | | Range | | Missings | | Mean levels and Standard Deviations | | | | | | Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Baseline | | COVID19 survey | | Total | | |
| | Items | Min | Max | *N* | % | Mean | SD | Mean | SD | Mean | SD | *p* |
| Interview characteristics | | | | | | | | | | | | |
| Int. # contacts | 1 | 1 | 32 | - | - | 3.35 | 2.62 | 3.04 | 1.88 | 3.24 | 2.39 | 0.00 |
| Interviewer opp. sex | 1 | 0 | 1 | - | - | 0.46 | - | 0.53 | - | 0.48 | - | 0.00 |
| Interviewer age w11 | 1 | 25 | 85 | - | - | 63.17 | 10.16 | 63.05 | 10.35 | 63.13 | 10.22 | 0.77 |
| Interviewer age w11 $\hat{2}$ | 1 | 625 | 7225 | - | - | 4093.97 | 1184.62 | 4082.02 | 1201.87 | 4089.85 | 1190.36 | 0.81 |
| Interviewer low education | 1 | 0 | 1 | - | - | 0.60 | - | 0.62 | - | 0.61 | - | 0.25 |
| Int. duration w11 in 10 min | 1 | 3 | 21 | 27 | 1.10 | 7.26 | 1.92 | 6.95 | 1.84 | 7.15 | 1.90 | 0.00 |
| Int. duration w11 in 10 $min^2$ | 1 | 12 | 470 | 27 | 1.10 | 56.45 | 34.88 | 51.81 | 30.73 | 54.85 | 33.57 | 0.00 |
| HH size | 1 | 1 | 13 | 1 | 0.04 | 3.71 | 1.38 | 3.76 | 1.23 | 3.73 | 1.33 | 0.40 |
| HH $size^2$ | 1 | 1 | 169 | - | - | 15.69 | 11.77 | 15.66 | 11.05 | 15.68 | 11.53 | 0.95 |
| No. of missings w11 (log.) | 1 | −5.4 | −0.4 | - | - | −3.66 | 0.73 | −3.79 | 0.66 | −3.70 | 0.71 | 0.00 |
| Int. participation w12 | 1 | 0 | 1 | - | - | 0.67 | - | 0.92 | - | 0.76 | - | 0.00 |
| Int. part. partner w11 | 1 | 0 | 1 | - | - | 0.04 | - | 0.06 | - | 0.05 | - | 0.00 |
| Cohab. parent | 1 | 0 | 1 | - | - | 0.93 | - | 0.95 | - | 0.94 | - | 0.06 |
| Observations | | | | | | 1621 | | 851 | | 2472 | | |

Table 2
*Model estimates*

| | Model 1 Uncorrected | | Model 2 Heckman model | | | Model 3 Uncorrected | | Model 4 Heckman model | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\hat{b}$ | SE | $\hat{b}$ | SE | $\chi^2$ | $\hat{b}$ | SE | $\hat{b}$ | SE | $\chi^2$ |
| *Prediction equation: Predicting adherence to COVID-19 regulations* | | | | | | | | | | |
| Women | 0.30*** | 0.07 | 0.15 | 0.08 | 5.20* | 0.25** | 0.08 | 0.18* | 0.09 | 1.53 |
| Age 17+ | 0.18* | 0.07 | 0.20*** | 0.08 | 0.77 | 0.17* | 0.07 | 0.19** | 0.07 | 1.05 |
| Single | 0.09 | 0.09 | 0.00 | 0.09 | 3.18 | 0.02 | 0.09 | −0.01 | 0.09 | 1.02 |
| Enrolled in higher education | 0.00 | 0.08 | −0.17 | 0.10 | 5.10* | 0.05 | 0.08 | −0.02 | 0.09 | 1.51 |
| Education: other | 0.04 | 0.14 | 0.04 | 0.14 | 0.00 | 0.03 | 0.14 | 0.03 | 0.14 | 0.01 |
| Enrolled in vocational training | −0.25 | 0.17 | −0.08 | 0.18 | 2.95 | −0.24 | 0.17 | −0.18 | 0.17 | 1.21 |
| Migration background (1+2 gen.) | −0.01 | 0.08 | 0.14 | 0.09 | 4.82* | −0.04 | 0.09 | 0.01 | 0.09 | 1.43 |
| Urban | −0.02 | 0.08 | 0.02 | 0.08 | 1.50 | −0.03 | 0.08 | −0.01 | 0.08 | 1.03 |
| East Germany | −0.14 | 0.10 | −0.10 | 0.10 | 1.04 | −0.16 | 0.10 | −0.14 | 0.10 | 0.58 |
| HH economic deprivation | - | - | - | - | - | −0.02 | 0.04 | −0.01 | 0.04 | 0.77 |
| Physical health | - | - | - | - | - | −0.01 | 0.00 | −0.01 | 0.00 | 0.43 |
| Depressive symptoms | - | - | - | - | - | 0.02 | 0.10 | 0.00 | 0.10 | 0.52 |
| Trust | - | - | - | - | - | 0.00 | 0.05 | −0.03 | 0.06 | 1.50 |
| Conduct problems | - | - | - | - | - | 0.10 | 0.15 | 0.17 | 0.16 | 1.24 |
| Pro-social behaviour | - | - | - | - | - | 0.14 | 0.12 | 0.12 | 0.12 | 0.72 |
| Hyperactivity | - | - | - | - | - | −0.27** | 0.09 | −0.26** | 0.09 | 0.64 |
| Peer problems | - | - | - | - | - | 0.37** | 0.11 | 0.36** | 0.11 | 0.54 |
| Neuroticism | - | - | - | - | - | −0.02 | 0.05 | −0.03 | 0.05 | 0.59 |
| Extraversion | - | - | - | - | - | −0.12** | 0.04 | −0.11* | 0.05 | 1.06 |
| Agreeableness | - | - | - | - | - | 0.13** | 0.05 | 0.14** | 0.05 | 0.84 |
| Conscientiousness | - | - | - | - | - | −0.01 | 0.05 | −0.01 | 0.05 | 0.27 |
| Openness | - | - | - | - | - | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 |
| Machiavellianism | - | - | - | - | - | −0.04 | 0.05 | −0.05 | 0.05 | 0.27 |
| Narcism | - | - | - | - | - | −0.03 | 0.06 | −0.02 | 0.06 | 0.04 |
| Constant | −0.28* | 0.11 | 0.58* | 0.24 | - | −0.09 | 0.48 | 0.32 | 0.55 | - |
| *Selection equation: Predicting survey non-response (Probit model)* | | | | | | | | | | |
| Women | - | - | 0.31*** | 0.06 | - | - | - | 0.33 | 0.07 | - |
| Age 17+ | - | - | −0.05 | 0.06 | - | - | - | −0.04 | 0.06 | - |
| Single | - | - | 0.22** | 0.08 | - | - | - | 0.25** | 0.08 | - |
| Enrolled in high education | - | - | 0.29*** | 0.07 | - | - | - | 0.28*** | 0.07 | - |
| Education: other | - | - | 0.04 | 0.11 | - | - | - | 0.05 | 0.11 | - |
| Enrolled in vocational training | - | - | −0.33** | 0.12 | - | - | - | −0.34** | 0.12 | - |
| Migration background (1+2 gen.) | - | - | −0.25*** | 0.07 | - | - | - | −0.23*** | 0.07 | - |
| Urban | - | - | −0.10 | 0.06 | - | - | - | −0.10 | 0.06 | - |
| East Germany | - | - | −0.05 | 0.08 | - | - | - | −0.04 | 0.08 | - |
| Number of Int. contacts w11 | - | - | −0.03** | 0.01 | - | - | - | −0.03** | 0.01 | - |
| Interviewer has opposite sex w11 | - | - | 0.12* | 0.05 | - | - | - | 0.12* | 0.06 | - |
| Interviewer age w11 | - | - | −0.01 | 0.02 | - | - | - | 0.00 | 0.02 | - |
| Interviewer age w11$^2$ | - | - | 0.00 | 0.00 | - | - | - | 0.00 | 0.00 | - |
| Interviewer: low education | - | - | 0.07 | 0.05 | - | - | - | 0.07 | 0.06 | - |
| Interview duration w11 | - | - | −0.02 | 0.06 | - | - | - | −0.03 | 0.07 | - |
| Interview. duration w11$^2$ | - | - | 0.00 | 0.00 | - | - | - | 0.00 | 0.00 | - |
| HH size | - | - | 0.09 | 0.08 | - | - | - | 0.12 | 0.09 | - |
| HH size$^2$ | - | - | −0.01 | 0.01 | - | - | - | −0.01 | 0.01 | - |
| No. of missings w11 (log.) | - | - | −0.04 | 0.04 | - | - | - | −0.07 | 0.04 | - |
| Int. participation w12 | - | - | 0.90*** | 0.08 | - | - | - | 0.96*** | 0.08 | - |
| Int. part. partner w11 | - | - | 0.35** | 0.13 | - | - | - | 0.41** | 0.14 | - |
| Cohabiting with parent(s) | - | - | −0.04 | 0.15 | - | - | - | −0.03 | 0.16 | - |
| HH econ. deprivation | - | - | −0.03 | 0.03 | - | - | - | −0.03 | 0.03 | - |
| Physical health (SF12) | - | - | 0.00 | 0.00 | - | - | - | 0.00 | 0.00 | - |
| Depressive symptoms | - | - | 0.08 | 0.08 | - | - | - | 0.10 | 0.08 | - |

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| | Model 1 Uncorrected | | Model 2 Heckman model | | | Model 3 Uncorrected | | Model 4 Heckman model | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\hat{b}$ | SE | $\hat{b}$ | SE | $\chi^2$ | $\hat{b}$ | SE | $\hat{b}$ | SE | $\chi^2$ |
| Trust | - | - | 0.14*** | 0.04 | - | - | - | 0.15*** | 0.04 | - |
| Conduct problems | - | - | −0.06 | 0.11 | - | - | - | −0.12 | 0.12 | - |
| Pro-social behaviour | - | - | 0.07 | 0.09 | - | - | - | 0.05 | 0.10 | - |
| Hyperactivity | - | - | −0.15* | 0.07 | - | - | - | −0.08 | 0.08 | - |
| Peer problems | - | - | 0.16 | 0.09 | - | - | - | 0.07 | 0.10 | - |
| Neuroticism | - | - | −0.01 | 0.04 | - | - | - | 0.00 | 0.04 | - |
| Extraversion | - | - | −0.11** | 0.03 | - | - | - | −0.09* | 0.04 | - |
| Agreeableness | - | - | 0.01 | 0.04 | - | - | - | −0.04 | 0.04 | - |
| Conscientiousness | - | - | −0.02 | 0.04 | - | - | - | −0.02 | 0.05 | - |
| Openness | - | - | 0.01 | 0.04 | - | - | - | 0.00 | 0.04 | - |
| Machiavellianism | - | - | −0.01 | 0.04 | - | - | - | 0.00 | 0.04 | - |
| Narcism | - | - | −0.01 | 0.04 | - | - | - | −0.01 | 0.05 | - |
| Constant | - | - | −1.69* | 0.72 | - | - | - | −2.07** | 0.76 | - |
| atanh($\rho$) | - | - | −0.75*** | 0.19 | - | - | - | −0.31 | 0.19 | - |
| log($\sigma$) | - | - | 0.12 | 0.06 | - | - | - | −0.03 | 0.04 | - |
| $\rho$ | | - | −0.63 | | - | | - | −0.3 | | - |
| $\sigma$ | | - | 1.13 | | - | | - | 0.97 | | - |
| $\lambda$ | | - | −0.71 | | - | | - | −0.29 | | - |
| $\chi^2$ | | - | 20.86 | | - | | - | 77.02 | | - |
| $R^2$ | | 0.03 | - | | - | | 0.10 | - | | - |
| N | | 851 | 2472 | | - | | 851 | 2472 | | - |

* $p < 0.01$ ** $p < 0.05$ *** $p < 0.001$

*demographics*, being female (10.5 p.p.), single (7.8 p.p.), and currently being enrolled in higher education (8.8 p.p.; ref. lower education) increased chances of participation while being enrolled in vocational training (−10.7 p.p.) or having a migration background (−7.3 p.p.) reduced them. Of all the indicators pertaining to *context*, *personal* and *personality characteristics*, only greater level of general trust increased the chance of participation in the COVID-19 study (4.8 p.p. per unit), while extraversion decreased it (−2.8 p.p. per unit).

### 4.2 nonresponse bias in adherence to COVID-19 regulations

In the next step, we examined the *bias of the sample mean* of compliance with COVID-19 regulations due to selective nonresponse (see Figure 2). The first estimate pertains to the uncontrolled, that is unweighted, sample mean which serves as reference. As the scale indicating adherence to COVID-19 regulations was $z$-standardised, the mean of its distribution was zero and the standard deviation one. For the next predictions, weights to correct for nonresponse were applied. These weights were constructed to control for additional sets of variables in each step. First, socio-demographics and context variables were included which, however, did not result in a significant difference. Thereafter, we included all other personal indicators. Applying these weights produced a significantly smaller mean level ( $\bar{x} = -0.08$, $p = 0.03$). We then included interview characteristics for survey nonresponse which resulted in a further decline of the mean level ( $\bar{x} = -0.12$, $p < 0.01$). These findings suggest that, without any weighting, the sample mean of compliance with COVID-19 regulations is overestimated by about 0.1 standard deviations.

Finally, we examined the *nonresponse bias in individual predictors* of compliance with COVID-19 regulations. To do so, we applied Heckman selection models with two sets of predictors for compliance with COVID-19 regulations, one containing only *socio-demographic and context characteristics* which are often controlled for in COVID-19 studies, and the other including the full set of individual indicators.

The model with the full set of variables is displayed in Figure 3 (Table 2, Model 4). On the y-axis, the probability of participation in the COVID-19 survey is displayed. Left from the vertical dashed line, interview characteristics that predict only survey participation but not compliance with COVID-19 regulations are shown: For instance, if the interviewer was of the opposite sex to the respondent in the baseline interview, the probability of participation in the COVID-19 survey was significantly higher. Right from the vertical dashed line, characteristics are displayed that contribute both to survey participation (y-axis) as well as adherence to COVID-

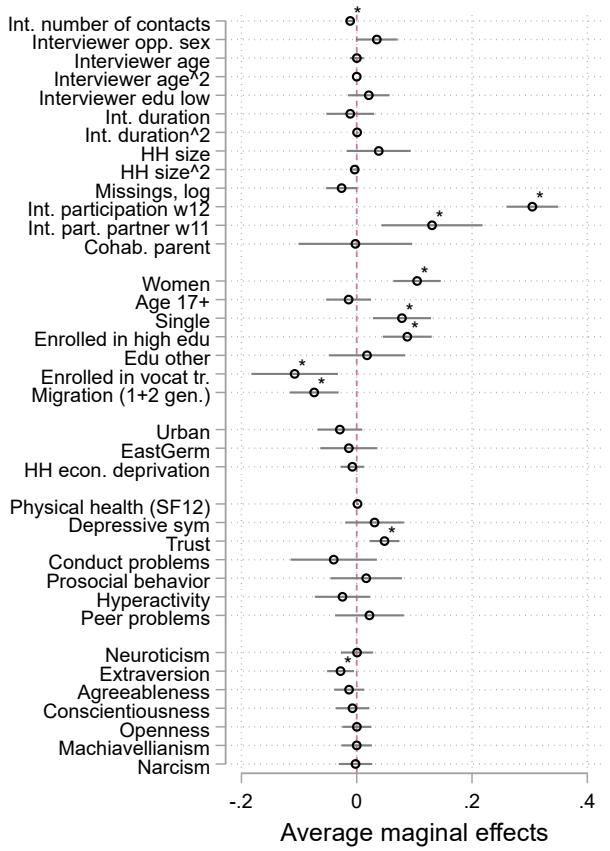


*Figure 1*. Probability of participation (AME) in the COVID-19 survey based on probit model (95% C.I., $p < 0.05$ significance level indicated with asterisk)

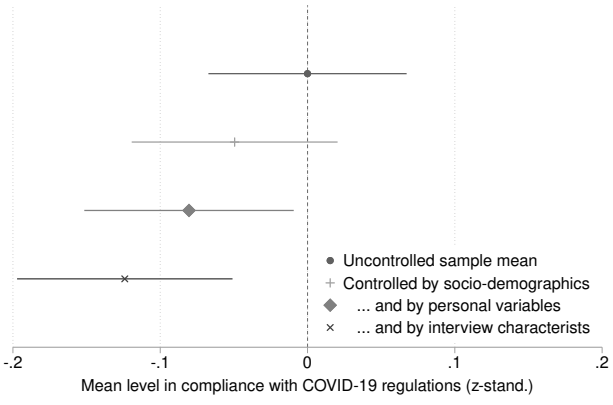


*Figure 2*. Sample means (and 95% C.I.) of compliance with COVID-19 regulations ($z$-standardised) weighted for different sets of predictors

19 regulations (x-axis). These estimators relate to the simultaneously estimated OLS regressions, which included the correction factor for selective survey nonresponse: For instance, women were significantly more likely than men to participate in the COVID-19 study and were more adherent to COVID-19 regulations. Extraversion, on the other hand, was associated with lower levels of survey participation and lower adherence to the regulations. The socio-demographic variables of education, being single, and having a migration background, as well as higher levels of trust, were not associated with adherence but with the probability of survey participation. In contrast, lower levels of hyperactivity and higher levels of agreeableness as well as peer problems were positively associated with adherence to COVID-19 regulations but not with survey participation.

To assess the extent of bias, we compared predictors of the Heckman selection models (Table 2, Model 2 and 4) with the estimates of an uncorrected OLS regression (Models 1 & 3). First, the models only containing socio-demographic variables were investigated (Model 1 vs 2). The estimate of gender of the uncorrected OLS regression was twice the size of that of the Heckman selection model. This indicates that selective nonresponse in the COVID-19 study led to an overestimation of the gender effect on compliance with COVID-19 regulations. In contrast, the size of the estimate for education tended to be underestimated: its absolute value was larger in the Heckman selection model. However, in both models, the association with adherence did not significantly differ between respondents who were currently in a lower education track compared to those in higher education. The association of migration background and adherence to COVID-19 regulations is opposite in both models: Respondents with a migration background appear to be more adherent than an uncorrected regression would suggest.

If information on personal and personality characteristics of the respondent is included, significant differences between a simple OLS model (Model 3) and the Heckman selection model (Model 4) disappear. The estimates of the significant characteristics were very similar, with higher levels of adherence to COVID-19 regulations indicated for women and older respondents, those exhibiting higher levels of agreeableness and lower levels of peer problems, hyperactivity, and extraversion. All other predictors were not shown to be influential.

## 5 Discussion

The current paper examined selective nonresponse in a COVID-19 survey as a source for biased estimates of adherence to COVID-19 regulations. The study was based on a random sample of young adults living in Germany after the first lock-down in spring 2020. We argued that, due to similarities in the decision-making processes, central characteristics might predict both survey nonresponse and adherence

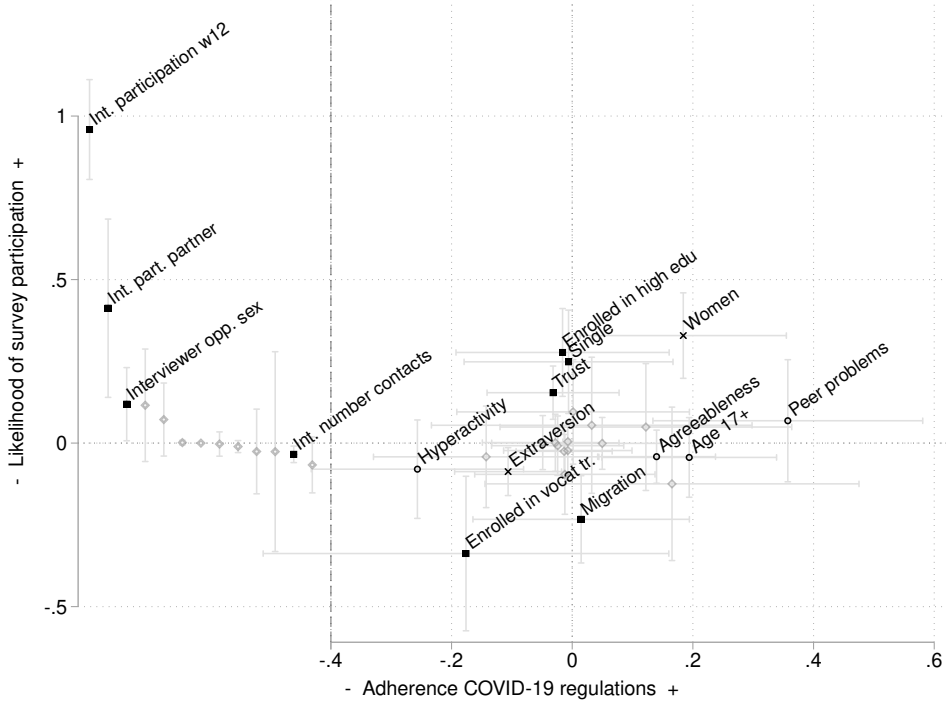


*Figure 3*. Heckman selection model predicting survey participation and adherence to COVID-19 regulations. *Note:* For readability, non-significant characteristics are unlabelled and displayed in light-grey. Squares indicate characteristics significantly predicting survey participation only; hollow circles indicate characteristics significantly predicting adherence to COVID-19 regulations only; crosses indicate characteristics significantly predicting both survey participation and compliance with regulations.

to COVID-19 regulations. Accordingly, we expected individuals who were less likely to participate in the study to also be those who were less adherent (and vice versa). Because these individuals would not be observed in the study, the mean level of adherence in the sample would be overestimated compared to the true mean level of the population. Moreover, predictors of adherence would be biased.

We found clear evidence for a positively biased mean level in the sample. This overestimation, however, was less severe than expected. Moreover, while we expected to find a large variety of common indicators that influenced survey participation *and* adherence to COVID-19 regulations, only two characteristics did: gender and extraversion. This means that the above-average participation of women and introverted individuals with their above-average level of adherence to COVID-19 regulations positively biased the mean level in the sample (see Figure 3 or Table 2, Model 4) . Lastly, biases in the predictor strength were expected to be present for several variables if selective nonresponse was not taken into account. However, only three indicators were indeed biased. We found that if the set of variables predicting adherence to COVID-19 regulations only included basic sociodemographic variables, the positive association of women was overestimated while the associations for education and migration background were underestimated. Considering a larger set of variables strongly reduced the biases in the estimators.

Our results can generally be interpreted as good news: Despite detecting a blind spot in the sample, predominantly amongst men, singles, and individuals with a lower educational level, migration background, lower levels of trust and high levels of extraversion (see Figure 1), it seems that this nonresponse is not as strongly correlated with adherence as expected. This means that there are common characteristics predicting survey participation and adherence, but there must be some other characteristics influencing both decisions, separately or in opposite directions.

We suggest, in order to tackle the bias in the predictors of adherence, a broader range of variables beyond sociodemographics to be included. However, to correct for the bias in the mean level, more sophisticated survey methods need to be applied; information on the target population is necessary, which is often not easily accessible for data users. Accordingly, data providers might want to provide weights

addressing issues of nonresponse. In general, we understand random samples as a precondition for high quality (COVID-19) studies. Although selective participation remains a potential threat to the generalisability of the findings, the nonresponse bias can be quantified and treated. In contrast, convenience samples, which are common in this field of research, are threatened with another term of error: self-selection (De Man et al., 2021; Schaurer & Weiß, 2020). They are, hence, not able to properly represent the target population because the self-selection criteria remain unclear. For instance, a self-selection criterion could be the survey topic, which could lead to a bias in respondents with a particular interest (in terms of leverage Groves et al., 2000). This bias is, however, difficult to treat (see Bethlehem (2015) and Peytchev (2013); and for recent developments questioning this assumption see Cornesse et al. (2020), Kohler et al. (2019)).

The current study has some limitations. The study examined young adults (born between 2001 and 2003) living in Germany at the end of the first lock-down. Over time and across societal contexts, the prevalence—in total and for specific subpopulations—as well as the knowledge on the virus have changed. Accordingly, individual factors of adherence to the regulations might be different or have changed as well. Health behaviour might also differ across ages, with increasing age leading to shifting biographical challenges (e.g., enrolment in school versus labour force participation, (not) having children) and an increased risk of a severe course of the disease (including an increased perception of this risk, see Health Belief Model, but see Daoust (2020) for an identification of a non-linear relationship of age with COVID-19 related health behaviour). Therefore, the current sample might have a different level of adherence than the overall German population and the current findings should not be generalized to other age groups. Furthermore, we focussed on an overall indicator of adherence to COVID-19 regulations, although different facets (e.g., hygiene, social distancing, wearing masks) might exhibit different levels of and predictors for adherence. Additionally, we were not able to control for a potential cross-sectional nonresponse bias for the baseline observation. Baseline nonresponse is difficult to evaluate. The pairfam team provided weights (Wetzel, Schumann, & Schmiedeberg, 2021) generally showing that, for instance, lower education and migration background tend to be associated with nonresponse. While this must be interpreted with caution, as also the interview mode and the topics have changed, it seems that the correction of the Heckman models are only a first step in the direction of correcting nonresponse and that the presented changes might be even more substantial. Lastly, while it can be argued that internet users might differ from non-users (Schnell, Noack, & Torregroza, 2017, for health differences), the strength of our study is that we do not rely on a web-survey only. Instead, the analysis is based on a high-quality face-to-face study that functions as benchmark for the follow-up web-survey. Accordingly, a multitude of information collected in the first observation allows us to create highly sophisticated weights. By including an extensive array of covariates relevant for survey participation and COVID-19-related behaviour, we were able to better correct for selection bias.

While the current study evaluated the extent of nonresponse bias in a COVID-19 study on adherence with governmental regulations, related fields of research might suffer under similar mechanisms of nonresponse. For instance, in the field of well-being, dissatisfied individuals with higher levels of strain might participate less frequently in COVID-19 studies. For those studies, in which the survey participation might be associated with the outcome of interest, extensive analyses of survey nonresponse should be conducted.

## 6 Conclusion

Previous research based on adherence to COVID-19 regulations has frequently ignored patterns of nonresponse. The study demonstrated that this can led to systematic overestimations of the mean level of adherence to COVID-19 regulations and biased estimates of the predictors of COVID-19 related health behaviour. In the still growing amount of COVID-19 research, attention needs to be drawn to the data collection process as well as the correction of nonresponse bias. In convenience samples, participation is self-selected and nonresponse patterns cannot be observed. As the study shows, even in high quality random sample online studies, variables of interest might be biased if the patterns of selection are not taken into account. This is particularly the case in bivariate descriptive settings, while in multivariate models nonresponse can be tackled by including characteristics predicting both survey participation and health behaviour. Researchers need to account for survey nonresponse in their analyses in order to provide reliable information as basis for policy makers.

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