Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Fear and anxiety in the face of COVID-19: Negative dispositions towards risk and uncertainty as vulnerability factors

Philip Millroth [a,*], Renato Frey [b]

[a] Uppsala University, Uppsala, Sweden
[b] University of Basel, Switzerland

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ABSTRACT

In the face of the COVID-19 pandemic it is important to identify factors that make people particularly vulnerable of developing mental-health issues in order to provide case-specific treatments. In this article, we examine the roles of two psychological constructs – originally put forth in the behavioral decision sciences – in predicting interindividual differences in fear responses: general risk aversion (GRA) and intolerance of uncertainty (IU). We first provide a review of these constructs and illustrate why they may play important roles in shaping anxiety-related disorders. Thereafter we present an empirical study that collected survey data from 550 U.S. residents, comprising self-assessments of dispositions towards risk and uncertainty, anxiety- and depression levels, as well as demographic variables – to thus test the extent to which these psychological constructs are predictive of strong fear responses related to COVID-19 (i.e., mortal fear, racing heart). The results from Bayesian multi-model inference analyses showed that GRA and IU were more powerful predictors of fear responses than demographic variables. Moreover, the predictive power of these constructs was independent of general anxiety- and depression levels. Subsequent mediation analyses showed that the effects of GRA and IU were both direct and indirect via anxiety. We conclude by discussing possible treatment options, but also highlight that future research needs to further examine causal pathways and conceptual overlaps.

1. Introduction

A pandemic such as COVID-19 can have diverse effects on people's mental health, including anxiety and fear responses (e.g., Ahorsu et al., 2020; Holmes et al., 2020; Qiu et al., 2020; Rajkumar, 2020; Roy et al., 2020). In order to provide case-specific treatments (Holmes et al., 2020) it is important to identify robust factors that make people particularly vulnerable to developing such mental-health issues. Several vulnerability factors are obvious and easily identified (e.g., people with previous and/or ongoing mental-health issues; people that suffer direct trauma from the pandemic, such as health-care workers and relatives of the diseased). In this article we focus on two less obvious but potentially important vulnerability factors: individuals' psychological dispositions towards risk and uncertainty, as operationalized by the psychological constructs of *general risk aversion* (GRA) and *intolerance of uncertainty* (IU). Both of these constructs are widespread in the behavioral decision sciences, but arguably still somewhat less prominent in the clinical sciences.

We thus start with a brief review of different conceptualizations of *risk* and *uncertainty*, and then introduce the psychological constructs that may capture individuals' dispositions towards these concepts (i.e., GRA and IU). In so doing we will illustrate why these constructs may play a major role in peoples' cognitive and behavioral response to the pandemic. Thus, for clinicians it may be useful to consider these constructs particularly in the face of the pandemic, as risk and uncertainty are likely at the center of many peoples' current concerns: Will I or a loved one contract the disease? Will I lose my job? How likely is the vaccine to work for future variants of the virus?

1.1. Definitions and conceptualizations of risk and uncertainty

The concepts of risk and uncertainty have adopted prominent roles in the behavioral sciences (Althaus, 2005; Li, Hills, & Hertwig, 2020), including in the classical theories of economic decision-making (e.g., Bernoulli, 1738/1954; Kahneman & Tversky, 1979; Neumann & Morgenstern, 1944/2007; Pascal, 1654/1991; Savage, 1954; Tversky and

Abbreviations: GRA, general risk aversion; IU, intolerance of uncertainty.

* Corresponding author at: Department of Psychology, Uppsala University, P.O. Box 1225, SE-751 42, Uppsala, Sweden.
E-mail address: philip.millroth@psyk.uu.se (P. Millroth).

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Kahneman, 1992) as well as the study of cognitive processes and personality (e.g., Lichtenstein & Slovic, 2006; Lopes, 1987; Frey, Richter, Schupp, Hertwig, & Mata, 2021; Mishra, Barclay, & Sparks, 2017; Simon, 2000; Zhang, Highhouse, & Nye, 2019). More recently, these concepts have also started to be adopted in clinical psychology and psychiatry (e.g., Bishop & Gagne, 2018; Buhr & Dugas, 2002; Carleton, 2016; Grupe & Nitschke, 2013; Hasler, 2012; Lorian & Grisham, 2011).

For *risk* several different conceptualizations have been proposed (Aven, 2012), forming two separate – but not necessarily incompatible – categories: an economic and a clinical perspective (Schonberg, Fox, & Poldrack, 2011). According to the economic perspective, risk typically refers to situations in which decision makers know the exact probability distributions over possible outcomes (Knight, 1921), hence capturing *outcome variance* (note that the probabilities of different outcomes may be explicitly stated or internally represented by the individual)[1] . Thus, the term risk does not necessarily make a reference to whether a probabilistic outcome is good (i.e., has high utility) or bad (i.e., has low utility), as the outcomes of a *risky* option could, in principle, involve only gains (i.e., an attractive vs. a less attractive reward), only losses (an unpleasant vs. a less unpleasant loss), or gains *and* losses (for reviews, see Camerer et al., 2011; Gigerenzer, Swijtink, Porter, & Daston, 1990). By contrast, the clinical perspective typically describes risk as a behavior with potentially harmful consequences, thus conceptualizing risk as a *threat* (i.e., behaviors with short-term rewards but potential downside risks for health or mental wellbeing in the long run; Carleton, 2016; Grupe & Nitschke, 2013).

As compared to the concept of risk, *uncertainty* has been defined in even more diverse ways. A first notion relates back to situations of decisions under risk as introduced above: Specifically, although the probabilities of different outcomes are known in such situations, one cannot know, by definition, which of these outcomes will eventually realize as a result of the stochastic process ("randomness"); that is, such *aleatory uncertainty* (or statistical uncertainty) is an inherent property of risk and cannot be reduced (Paté-Cornell, 1996; Shaker & Hüllermeier, 2020; Spiegelhalter, 2008). Conversely, *epistemic uncertainty* refers to situations in which a person in principle *could* know about the likelihoods of different outcomes – but effectively does not; for instance, due to a lack of information acquisition and gathering insights about established facts.

Finally, another aspect of uncertainty comprises the concept of *ambiguity*. From an economic perspective, ambiguity historically refers to situations in which the probability distributions cannot be internally represented by some estimate – as famously illustrated by Ellsberg (1961): In this experiment, participants were asked to guess the color of a marble after having drawn from an urn consisting of 100 marbles, either red or blue, but without knowing how many of each color were in the urn. The problem of forming approximations of probability distributions in such instances can be further complicated if there is ambiguity about whether all possible outcomes are represented in the decision set or not (Keynes, 1921). More recently, decision scientists have come to use the term ambiguity also in reference to the notion that properties of the stimuli themselves (e.g., the marbles) may be obscured (for review, see Smithson, Priest, Shou, & Newell, 2019). For example, we may know that there are two types of marbles in the urn but do not know anything about their color. This definition of ambiguity as uncertainty about properties of present or future stimuli is arguably the most influential in the clinical sciences (for review, see Hillen, Gutheil, Strout, Smets, & Han, 2017).

1.2. Psychological dispositions towards risk and uncertainty

A key characteristic of peoples' reactions regarding both risk and uncertainty is that they typically have relatively averse dispositions towards the two (e.g., Frey, Pedroni, Mata, Rieskamp, & Hertwig, 2017; Linnér et al., 2019; Lopes, 1987). Although some intraindividual variability exists across various domains of life, giving rise to domain-specific risk preferences (e.g., Weber, Blais, & Betz, 2002; Frey, Duncan, & Weber, 2020), an increasing amount of evidence suggests that people may also have relatively domain-general risk preferences (e.g., Frey et al., 2017; Highhouse, Nye, Zhang, & Rada, 2017; Zhang et al., 2019). Specifically, despite that various "risk-taking measures" are quite diverse and may vary in the extent to which they focus on risk as outcome variance (i.e., economic definition) versus risk as a threat (i.e., clinical definition), empirically there is a considerable convergence across measures – at least across different self-reports, but not necessarily across different behavioral tasks (for possible explanations for this observation, see Millroth, Juslin, Winman, Nilsson, & Lindskog, 2020; Steiner & Frey, 2021; Steiner, Seitz, & Frey, 2021).

Moreover, people's general risk preferences (which is often also referred to as risk attitude, or when framed inversely as in the current article, as *risk aversion*) are considerably stable across time (e.g., Frey et al., 2017), and to some extent even appear to be genetically determined (Linnér et al., 2019). Finally, whereas people's general risk preferences show systematic associations with some sociodemographic variables such as gender (females being more risk averse; Frey et al., 2021), there exists ample interindividual variability even within subgroups; this variability is captured particularly well by self-report measures, which were found to reflect reliable and diagnostic signals (Frey et al., 2017; Millroth et al., 2020; Steiner & Frey, 2021; Zhang et al., 2019).

Similarly as for people's general risk preferences, it has repeatedly been documented that people show a strong aversion towards uncertainty, that is, not knowing what the immediate or distant future may hold (see e.g., Fox & Tversky, 1995; Hillen et al., 2017: note that this may comprise various notions of the term uncertainty as discussed above). The psychological construct of *intolerance of uncertainty* (IU) – an umbrella construct capturing individuals' aversion towards unknowns in the future – holds that situations defined as unpredictable, complex and/or insoluble are perceived as threatening and lead to an emotional state of uncertainty (for reviews on IU, see e.g., Carleton, 2016; Rosen, Ivanova, & Knäuper, 2014; Tanovic, Gee, & Joormann, 2018). The inability to tolerate uncertainty is considered a trait-characteristic, leading to a predisposition to react negatively to an uncertain event or situation, independent of its probability of occurrence. IU is thus considered to be a cognitive filter through which the environment is viewed and uncertainty is regarded as unacceptable. Albeit correlating with dispositions towards interpreting risk as threats, this shared variance is only a minor part of the IU-concept (Koerner, Mejia, & Kusec, 2017).

Crucially, a wealth of findings has shown that dispositions towards risk and uncertainty carry clinical implications, with negative attitudes in this respect being heavily entangled with psychiatric disorders, especially anxiety-related disorders (Bishop & Gagne, 2018; Buelow, 2020; Carleton, 2016; Grupe & Nitshke, 2013; Hartley & Phelps, 2012; Teng et al., 2016). For example, recent clinical research suggests that a disposition of being generally aversive towards risk can act to boost pre-existing anxiety by increasing fear levels, as well as being directly responsible for developing new anxiety by inducing avoidance bias (Charpentier, Aylward, Roiser, & Robinson, 2017; Maner & Schmidt,

[1] It should also be noted that, although Knight's (1921) hallmark definition of risk by necessity involves outcome variance, it was not until Markowitz (1952, 1991) developed *portfolio theory* that the actual concept of risk as outcome variance was mathematically formalized. Initially, the formalization of portfolio theory described the probability-weighted variance of expected returns – a definition that may imply more influence of the magnitude of the outcomes than as considered by Knight. After the second-half of the 20th century, an abundance of additional but strongly related operationalizations have been proposed in the economic sciences (for a review, see Linsley, Shrives, & Wieczorek-Kosmala, 2019). What they all have in common is that underlying probability distributions are central to capturing the element of risk.

2006). Similarly, IU is strongly related to anxiety disorders (e.g., Carleton, 2016). The clinical connection between anxiety and the risk- and uncertainty concepts is also supported by neurocognitive findings, showing that the biological systems- and processes that are activated by the various concepts of risk- and uncertainty is overlapping with those that involved in fear responses, threat detection, reinforcement learning, and reward processing – systems and processes that can lead to mental illnesses such as anxiety when malfunctioning (Glimcher & Fehr, 2014; Grupe & Nitschke, 2013; Poudel et al., 2020; Robinson, Pike, Cornwell, & Grillon, 2019).

1.3. The present empirical study: risk and uncertainty in the face of the pandemic

In the wake of the pandemic, we are all flooded with information that involves or refers to risk and uncertainty (e.g., "*the effective death rate from the disease is x percent*", "*you will probably not receive a vaccine before summer*", "*many restaurant owners are at risk of losing their businesses*", "*the vaccine comes with few risks*"). The realities of probability distributions, perceived future outcomes, and the uncertainties (reducible or irreducible) coupled with different outcomes, are overwhelming. Thus, the increased salience of these concepts brought forward by the pandemic may substantially affect people's behaviors and mental processes. More specifically, based on the reviewed literature we hypothesized that individuals with negative dispositions towards risk and uncertainty should be more prone to states of fear and anxiety in response to the pandemic. It is, however, harder to hypothesize *how much* people's dispositions towards risk and uncertainty will matter (i.e., on an absolute level; relative to each other).

Related studies have previously focused, for instance, on the relationship between fear of COVID-19 and media use (Mertens, Gerritsen, Duijndam, Salemink, & Engelhard, 2020), or on the relationship between stress related to COVID-19 and mood disorders (Asmundson et al., 2020). Yet, although these studies have discussed the roles of self-reported dispositions towards risk and uncertainty in light of their respective findings, to date no research has directly compared the predictive power of these constructs against the predictive power of demographic variables and ongoing mental-health issues (e.g., anxiety and depression) during an ongoing societal state of emergency.

Thus, the main aim of the current study was to determine to what extent dispositions towards risk and uncertainty may shape strong fear responses. For some researchers, fear and anxiety are undistinguishable, whereas others believe that they are distinct phenomena (for a discussion, see e.g., Steimer, 2002). In our study we draw upon the distinction (e.g., Carleton, 2012) that fear can be described as a protective response to a current, identifiable threat (e.g., being infected by the known virus when I go to the mall), typically accompanied by strong physiological reactions such as "fight or flight" – whereas anxiety occurs in response to a pending or potential threat that may or may not occur (e.g., the possibility of being infected by some virus, somewhere, sometime). The anxiety response is then accompanied by proactive avoidance behaviors, rather than the reactive fight-or-flight response associated with fear.

To avoid misguided expectations, we want to stress that the aim of the present study is not to provide an analysis of the role of specific risk- or uncertainty-related concepts. Rather, we aimed to use reliable measures that, in our opinion, collectively capture elements of *all* of the conceptualizations of risk and uncertainty discussed above – to thus examine the extent to which people's dispositions towards these concepts potentially shape fear responses to COVID-19 more generally.

In addition, we also aimed to test if engaging in the protective behaviors advocated by governments across the world (e.g., social distancing, washing hands) has the potential to moderate any detected relationships. The difficulty to treat mental-health issues that are dispositional in nature (e.g., Holmes et al., 2018; Robinson et al., 2019) speak against this possibility, as do the above distinction between fear and anxiety. Nevertheless, given the current unfolding of the crisis and the stakes at hand, it is a possibility worthy of empirical testing.

2. Methods

The study was pre-registered (https://osf.io/b5jhc) and conducted online via Amazon's Mechanical-Turk service. Previous research has shown that this population is valid for clinical assessments (Chandler & Shapiro, 2016; Ophir, Sisso, Asterhan, Tikochinski, & Reichart, 2020; Walters et al., 2018), although it should be noted that participants on MTurk typically exhibit higher levels of depression than the general population (Ophir et al., 2020).

2.1. Participants

Five-hundred and fifty (550) participants responded to the survey. The sample size was determined based on a preceding pilot-study (see pre-registration protocol), which showed that strong evidence could be obtained with 250 participants; approximately doubling the number of participants was thus foremost an action towards acquiring more fine-grained parameter estimates. Several reviews have asserted that online data is of no poorer quality as long as inattentive responses are screened for (Gosling & Mason, 2015; Hauser & Schwarz, 2016). It has been estimated that around 10–15 percent of MTurk respondents systematically produce inattentive responses (e.g., Fleischer, Mead, & Huang, 2015). The present study used a text question with a hidden attention check in the middle of the text where participants are told what they should respond to the question (see the pre-registration protocol). The attrition rate in the present study was 15 per cent.

Hence, 468 participants were included in the statistical analyses reported under 'Results': 283 females, 184 males, and one with no gender indicated. Mean age = 38.9 (*SD* = 11.8). Mean annual income = 46,303 US. Dollars (*SD* = 74,572). Mean highest achieved educational level = 3.00 (*SD* = .834) where 1 = have not finished high school, 2 = high school, 3 = undergraduate studies, 4 = master studies, and 5 = PhD.

2.2. Material & procedure

Participants responded to the following measures (in the stated order): *demographic information* (age, gender, wage, educational level, city of residence), *disposition towards risk and uncertainty*, *COVID-Fear*), *general anxiety levels, depression levels,* and *protective behaviors.*

2.2.1. Dispositions towards risk and uncertainty

As noted in the introduction, many measures often encompass elements of risk *and* uncertainty. In light of previous research indicating that it is possible to make at least a tentative distinction, we implemented the General Risk Propensity Scale (GRIPS: Zhang et al., 2019) as a measure of a person's disposition towards risk, and the Short Version of the Intolerance of Uncertainty Scale (Carleton, Norton, & Asmundson, 2007) as a measure of a person's disposition towards uncertainty.

The GRIPS consists of eight items, all targeting an individual's general disposition towards risk (e.g., "*Taking risks makeslife more fun*"; "*I commonly make risky decisions*"). Participants responded to the items on a scale from 1 to 5 where 1 = Strongly disagree, and 5 = Strongly agree. Participants' reversed item-scores were summed to an aggregate general risk aversion (GRA)-score for each participant.

The Short Intolerance of Uncertainty Scale (Carleton et al., 2007) consists of 12 items capturing an individual's general disposition towards uncertainty (e.g., "*Unforeseen events upset me greatly*"; "*Uncertainty keeps me from living a full life*". Participants responded to the items on a scale from 1 to 5 where 1 = Not at all characteristic of me, and 5 = Entirely characteristic of me. Participants' item scores were summed to an aggregate Intolerance of Uncertainty score (IU-score) for each participant.

2.2.2. COVID-Fear

We implemented the recently developed Fear of COVID-19 Scale (Ahorsu et al., 2020) which consists of seven items capturing an individual's fear response to the virus (e.g., "*It makes me uncomfortable to think about coronavirus-19*"; "*I am afraid of losing my life because of coronavirus-19*"). Participants responded to the items on a scale from 1 to 5 where 1 = Strongly disagree, and 5 = Strongly agree. For evidence showing that the scale is fear-specific and not heavily criterion-confounded with anxiety or distress, see Pakpour, Griffiths, & Lin, 2020). Participants' item scores were summed to an aggregate COVID-Fear score for each participant.

2.2.3. Anxiety and depression

The validated PROMIS-A and PROMIS-D scales were used to assess general anxiety and depression (Cella et al., 2019; Schalet et al., 2016). The scales are able to distinguish between depression and anxiety from a more general concept of negative affect (Schalet et al., 2016). The main analyses use the raw scores summed to one aggregate score for both scales (PROMIS-A and PROMIS-D). The results did not differ in any meaningful manner if t-scores were used instead.

2.2.4. Protective behaviors

We used eight items from recent COVID-research (Roy et al., 2020) to assess the degree to which participants engaged in protective behaviors in the last week (e.g., "*In the last week, how often have you avoided social contact?; "In the last week, how often do you feel the need to wash your hands?*" Participants responded to the items on a scale from 1 to 5 where 1 = Never, and 5 = Always. Participants' scores on the eight items were summed to an aggregate Protective Behavior score for each participant.

3. Results

Descriptive statistics for all measures as well as the raw data are available as Supplementary Material available from https://osf.io/jcnf3/. In what follows, our analyses will focus on the effects of general risk aversion (GRA) and intolerance of uncertainty (IU) that motivated the present study. Yet, there were also other notable effects that may be of interest for future research; to this end, Fig. 1 provides an overview of all correlations between the included variables.

To determine the predictive power of GRA-scores and IU-scores, we conducted Bayesian multi-model inference analyses using the R-package *BAS* (Clyde, 2020; Clyde, Ghosh, & Littman, 2011; Hinne, Gronau, van den Bergh, & Wagenmakers, 2020; van den Bergh et al., 2020) to i) obtain the importance of each independent variable in predicting the outcome variable, and ii) to obtain model-averaged coefficients. To this end, we adaptively sampled 1,000,000 models considering the model space including first-order interactions.

The analyses provided clear evidence that GRA and IU are strongly predictive of COVID-Fear, and that models including GRA and IU are much more probable in accounting for COVID-Fear than models including merely demographic variables (see Fig. 2, left panel). Specifically, among the 13 terms that achieved a posterior inclusion probability (i.e., considering a large model space of different combinations of terms) of larger than .5, 7 included the terms GRA or IU, or even both. Moreover, the two constructs as standalone predictors achieved posterior inclusion probabilities close to 1 (Fig. 2, left panel), implying an extremely high relevance of these predictors.

The comparisons of standardized regression coefficients further reflect the relevance of GRA and IU, showing that the effects of these constructs are clearly stronger than for demographic variables (see Fig. 2, right panel). Moreover, there were no indications that the effects of GRA and IU were moderated by engaging in protective behaviors or generally by demographics (i.e., Fig. 2 showed no positive evidence for interactions, with the exceptions for weak interactions between IU and education, and between GRA and gender).

Overall, these predictor variables permitted modeling fear from COVID-19 very well; although we generally refrain from focusing on individual regression models – as the key advantage of our multi-model inference analysis is that it fully incorporates the uncertainty that comes with model selection – for the purpose of illustration we report the

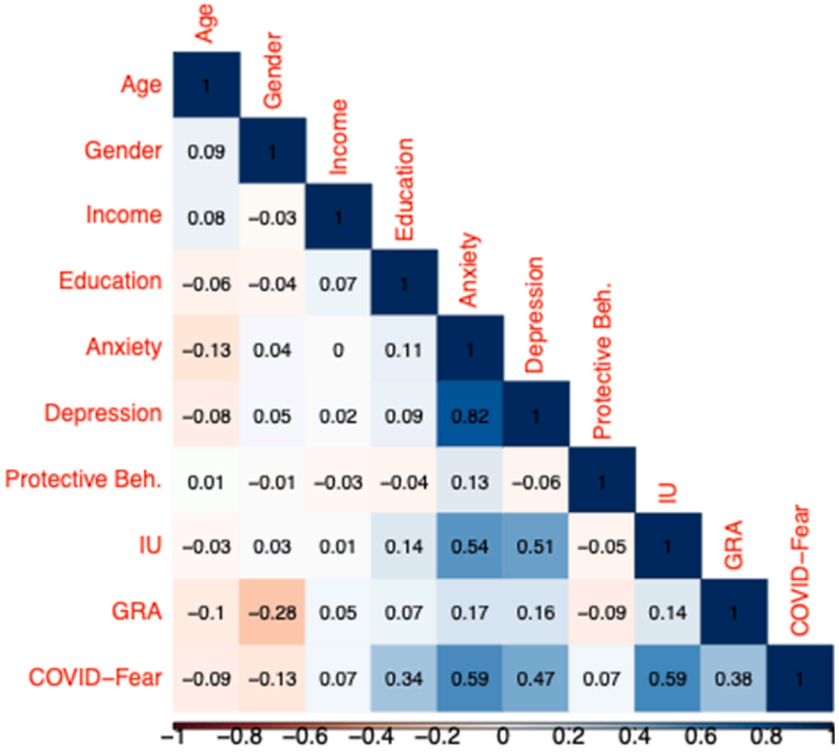

Fig. 1. Correlations between all independent variables (i.e., which were considered as predictors in the modeling analyses) and the dependent variable (Covid-19 Fear). GRA = general risk aversion; IU = intolerance of uncertainty. The variance inflation factor (VIF) ranged between 1.022 and 3.073.

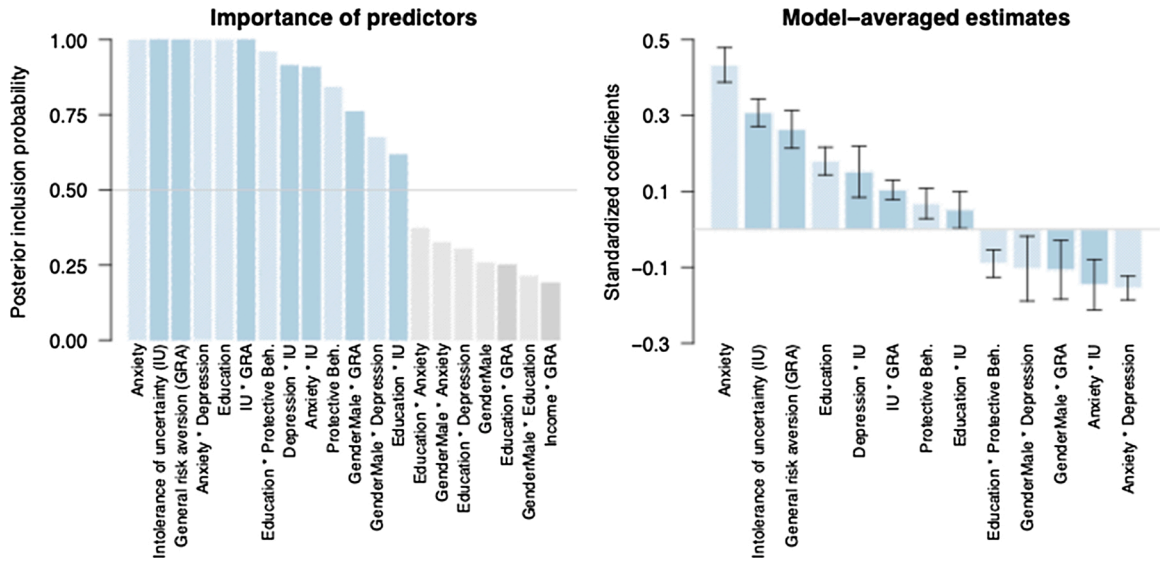

Fig. 2. The left panel shows the importance of the predictors (including first-order interactions) in terms of posterior inclusion probabilities (only the top 20 terms with highest inclusion probabilities are shown). The right panel shows the model-averaged estimates for the predictors that exceeded an inclusion probability of .5 (values represent standardized coefficients). Terms including general risk aversion (GRA) and intolerance of uncertainty (IU) are highlighted with dark bars. All results were obtained from Bayesian multi-model inference analyses and for predicting COVID-19 fear.

performance of a set of key models (i.e., in terms of explained variance). Specifically, the best model achieved an adjusted R^2 of .68, whereas the model including all first-order interactions achieved an adjusted R^2 of .67 and the model including only main effects an adjusted R^2 of .58.

To gauge if the predictive power may also imply a causal mechanism (e.g. Fairchild & McDaniel, 2017), we conducted mediation analyses in JASP (JASP Team, 2020) with COVID-Fear as outcome, either GRA or IU as main predictor, and Anxiety, Education, and GRA or IU (i.e., depending on which was used as main predictor) as mediators. This analysis showed that both GRA and IU yielded direct relationships with COVID-Fear (GRA: $b = .241$, z-value $= 8.28$, $p < .001$; IU $= b = .293$, z-value $= 9.67$, $p < .001$). Both GRA and IU also produced indirect effects via anxiety (GRA: $b = .241$, z-value $= 8.28$, $p < .001$; IU $= b = .170$, z-value $= 7.67$, $p < .001$).

4. Discussion

How best to predict fear from COVID-19 that may require prevention and case-specific treatment, to thus safeguard mental health during the pandemic? Beyond the obvious candidate predictors (e.g., general anxiety), we hypothesized that psychological dispositions towards risk and uncertainty – operationalized as general risk aversion (GRA) and intolerance of uncertainty (IU) – could be important factors to consider when aiming to understand mental-health problems arising from the COVID-19 pandemic, since individuals with negative dispositions towards risk and uncertainty are generally more prone to states of fear and anxiety. The results supported this claim. In fact, the predictive power of GRA and IU exceeded that of general depression levels and demographics (age, gender, income). Mediation analyses further showed that the effects of GRA and IU on COVID-Fear were both direct, as well as indirect via anxiety.

These findings align with and extend past and current research: First, the current observations are in line with the growing clinical literature connecting a negative disposition towards risk and uncertainty with fear- and anxiety levels (e.g., Carleton, 2016; Charpentier et al., 2017). Second, the finding that GRA and IU are related with each other, but still provide their own influence on fear and anxiety, is in line with previous findings showing that GRA can indeed be separated from IU (Koerner et al., 2017). These findings are also in line with other research on mental-health and COVID-19 that has identified a link between mental-health issues and dispositions towards risk and uncertainty (Bakioğlu, Korkmaz, & Ercan, 2020; McCleskey & Gruda, 2021; Parlapani et al., 2020; Satici, Saricali, Satici, & Griffiths, 2020; Smith, Twohy, & Smith, 2020). Collectively, these findings suggest that it could be instrumental for clinicians to take into account the roles of the psychological constructs of GRA and IU. The question thus arises: How to treat mental-health issues that to some extent appear to be linked to these constructs?

4.1. Available treatments for mental-health issues related to GRA and IU

Current treatments that focus *specifically* on shifting a negative disposition towards risk and uncertainty come in the form of cognitive behavioral therapy (CBT: Charpentier et al., 2017; Carleton et al., 2007; Hebert & Dugas, 2019; Lorian, Titov, & Grisham, 2012; Rodgers et al., 2017). For example, Hebert and Dugas (2019) propose that CBT can be tailored to decrease mental simulation of catastrophic future events – in other words, downplaying the threat component. According to Charpentier et al. (2017), the success of CBT in decreasing risk-induced anxiety may not be so much about desensitizing individuals to the object of their fears or having them ignore them, but rather showing them that they can successfully navigate past them (i.e., they can take a risk – e.g., go to school – without coming to harm), thus essentially reducing the level of epistemic uncertainty.

However, it should be recognized that situations where GRA and IU have clinical implications (e.g., the present pandemic) involve a complex puzzle in regards to which psychological components are most important in driving mental-health problems (e.g., (Taylor, Landry, Paluszek, Rachor, & Asmundson, 2020). Thus, a treatment plan for reducing pathological fears of COVID-19 will naturally also have to include interventions not specifically targeting GRA and IU. For example, recent pandemic-specific studies have argued for interventions targeting an individual's lack of social support (Asmundson et al., 2020; Xiao, Zhang, Kong, Li, & Yang, 2020). Of course, such interventions may prove challenging to implement since guidelines to decrease the spreading of the virus are in conflict with increased social engagement; that is, policy makers and clinicians should be aware that digital media has the potential both to increase and decrease social capital (for a recent review, see: Allcott, Braghieri, Eichmeyer, & Gentzkow, 2020). Thus, given the difficulty to implement such social-support

interventions, it may be even more important to consider GRA and IU as potential treatment targets.

4.2. Possible paths towards developing future treatments

Treating dispositional mental-health issues is difficult, and the effectiveness of most psychopharmacological and behavioral interventions do not exceed 50–60 per cent (e.g., Holmes et al., 2018). The disentanglement of the different psychological mechanisms at play offers the promise of increasing efficacy rates (for a discussion on *meta-cognitive* approaches towards developing therapy interventions, see e.g., Holmes et al., 2016): in our case this amounts to pinpointing the different mechanisms driving a person's disposition towards risk and uncertainty.

In the process of pinpointing these mechanisms, future research needs to acknowledge that that psychological constructs capturing dispositions toward risk and uncertainty, such as GRA and IU, may not clearly capture distinct conceptualizations of risk and uncertainty (for discussions, see e.g., Hillen et al., 2017; Gasiorek, Fowler, & Giles, 2019; Koerner et al., 2017). Notably, similar measurement-related concerns have been made in the behavioral decision sciences, with some studies highlighting that preferences towards economic risk and uncertainty are malleable, particularly when being elicited via behavioral tasks (e.g., assessing monetary gambles, card tasks; see e.g. Lichtenstein & Slovic, 2006; Pedroni et al., 2017; Millroth et al., 2020; Schürmann, Frey, & Pleskac, 2019; Steiner & Frey, 2021). In order to render possible specific hypotheses about which mechanisms should be targeted in, for example, CBT interventions it will be important to examine to what extent constructs such as GRA and IU manage to capture distinct conceptualizations. From the literature review provided in the introduction, we can immediately recognize a number of components that future studies should strive to examine more closely, namely: A person's subjective (i) degree of epistemic uncertainty regarding probabilities and outcomes, (ii) absence or presence of aleatory uncertainty, (iii) degree of threat, and (iv) degree of outcome variance.

4.3. Limitations

In what follows we would like to discuss three limitations of the current study. First, as with all observational survey studies, the present study cannot provide an account of the causal pathways involved.

Second, the sample we used (crowdsourcing-workers) limits the generalizability of our findings: Although, previous research has shown that this population is valid for clinical assessments (Chandler & Shapiro, 2016; Ophir et al., 2020; Walters et al., 2018), it has also been shown that crowdsourcing-workers typically exhibit higher levels of depression than the general population (Ophir et al., 2020). Thus, although our findings should be highly relevant for populations with existing mental-health issues, it remains to examine to what extent GRA and IU may induce fear also in more general populations.

Third, the present study builds on the assumption that a person's dispositions towards risk and uncertainty can be understood on a continuum (averse ⟵ → tolerant: see e.g., Weber & Milliman, 1997). Although emergent research has proposed that the end-points on this continuum may trigger different reinforcement mechanisms (positive vs. negative, see Freeland, Knes, & Robinson, 2020), a body of neurocognitive research has provided evidence that the same neurocognitive systems seem to be involved irrespective of whether people are considered *averse* or *tolerant* of risk and uncertainty (see e.g., Blum et al., 2000; Dayan & Berridge, 2014; Glimcher & Fehr, 2014; Grupe & Nitschke, 2013; O'Doherty, Cockburn, & Pauli, 2017; Yarosh et al., 2014).

4.4. Conclusions

The present study has highlighted that psychological dispositions towards risk and uncertainty play an important role in predicting – and thus potentially shaping – how individuals respond to the threat of COVID-19. Although treatment options in the face of the pandemic are scant and their effects to some extent unknown, the current study's findings may be informative for future research as well as clinical practice: Specifically, for the development of efficient treatments in future work it may be instrumental to consider people's dispositions towards the concepts of risk and uncertainty.

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Author contributions

Conceptualization, design of empirical study, and data collection: P. M. Data analysis and interpretation: P.M. and R.F. Writing of manuscript: P.M. and R.F.

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