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Development and cross-national validation of the PEPB: a pandemic and emergency preparedness and behaviours monitor in four European countries

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Research Article

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Development and cross-national validation of the PEPB: a pandemic and emergency preparedness and behaviours monitor in four European countries

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Abstract

Background The COVID-19 pandemic highlighted the critical role of population behaviour in controlling the devastating impact of a health emergency. The absence of a standardised, cross-national survey that monitors preparedness behaviours and their determinants limit timely, evidence-informed public health preparedness and policy development. This study introduces and validates the Pandemic and Emergency Preparedness Behaviour (PEPB) monitor, a theory-informed survey designed to assess behavioural preparedness for future pandemics and emergencies.

Methods Data were collected in March 2024 among adults aged ≥18 years in four European countries (the Netherlands, Spain, Ireland, and Slovenia; total N = 4,636). The PEPB monitor includes validated and new constructs covering preparedness and health behaviours, psychosocial determinants, preparedness perceptions, and self-reported health, theoretically supported by the COM-B model. Psychometric properties were examined using multigroup structural equation modelling, including tests of validity, internal reliability, and cross-national measurement invariance. Cross-national comparisons of preparedness-related behaviours and determinants were conducted, and illustrative regression analyses were performed to demonstrate policy-relevant use cases.

Results Most multi-item constructs demonstrated good internal reliability and adequate structural validity across countries. Metric invariance was supported for all scales, indicating that associations between constructs can be meaningfully compared cross-nationally. Scalar invariance was supported for all constructs, except for mental health, perceived likelihood of disaster occurrence, and perceived severity of disaster consequences. Substantial cross-national differences were observed in hygiene behaviours, household preparedness, institutional trust, health literacy, and conspiracy beliefs. Regression analyses illustrate how the PEPB monitor can be used to identify behavioural, social, and institutional determinants of key preparedness-relevant outcomes.

Conclusions By testing the survey's psychometric properties in diverse national settings, the PEPB monitor provides an empirical baseline reference for observing societal behavioural changes during future pandemic and health emergency threats. Substantial cross-national variation in preparedness-related behaviours and institutional trust indicates that behavioural readiness during non-crisis phases cannot be assumed. Continued implementation of the PEPB monitor over time across countries can support evidence-informed preparedness policy and strengthen societal resilience to future public health emergencies.

Clinical trial number: not applicable.'

Keywords: *Pandemic preparedness; health emergencies; Health behaviour; Behavioural determinants; Cross-national survey; Instrument development; Psychometric properties; Measurement invariance; Public health surveillance*

Highlights

- We developed a standardised behavioural monitor for pandemic preparedness
- The instrument was validated in four European countries
- Most constructs showed good reliability and cross-national comparability
- Key behavioural and institutional preparedness gaps were identified
- Findings inform preparedness policy during non-crisis (“cold”) phases

Background

Major infectious disease outbreaks, such as HIV, SARS ebola and COVID-19 have demonstrated the importance of human behaviour to reducing virus transmission (WHO, 2020). While international infection rates, hospital admissions, and vaccine uptake were closely monitored and compared prior to and during the COVID-19 pandemic (WHO, 2005), an infrastructure for comparable international data on behaviour relevant in a pandemic scenario (e.g. hand washing) and determinants of such behaviours (e.g. trust in government or social support) were largely absent. Various efforts were made to facilitate monitoring of behaviours and behavioural determinants and to offer evidence-based strategies to support behaviour change in early phases of the pandemic (e.g., Byrne-Davis et al., 2022; Ruggeri et al., 2024; van Bavel et al., 2020; Betsch, 2020; De Bruin et al., 2021; Van den Boom et al., 2023; Lewandowsky et al., 2023; Beca-Martinez et al., 2022; Bacon et al., 2025).

Evaluations of these efforts (e.g., Baggio et al., 2024) highlight that although useful behavioural knowledge contributions were made during the pandemic, these were limited by a lack of measurement infrastructure and baseline data during a cold phase, when no imminent threat was present. Without comparable and baseline data, contextualising and implementing behavioural recommendations was complicated. Together, these experiences highlight the urgent need for a standardised, cross-nationally applicable survey for assessing pandemic preparedness and health related behaviours.

Prior to the COVID-19 pandemic, several survey instruments were designed to assess individual and community preparedness behaviours in response to emerging infectious diseases and other public health threats. For example, preparedness and risk perception were examined in the context of avian influenza (H5N1) (Lau et al., 2010) and Ebola virus disease during the 2014-2016 outbreak (e.g., Kelly et al., 2015; Petrie, Faasse, & Thomas, 2016). In addition, broader disaster preparedness behaviours were assessed in general population studies (Inal, Atintas, & Dogan, 2018). Similarly, since the pandemic, a few projects have continued data collection with the aim of broadening the scope from COVID-19-relevant behaviours to adjacent behaviours such as vaccination or pandemic preparedness (e.g., Bacon et al., 2025). To the best of our knowledge, no dedicated pandemic preparedness behavioural monitor has been developed to measure collective behaviours and determinants that may be relevant during a cold phase of a pandemic.

In response, we developed the Pandemic and Emergency Preparedness Behaviour (PEPB) monitor with four European countries. The PEPB monitor is designed to measure preparedness-related behaviours, their determinants, and self-reported health during a cold phase, and to capture changes during a hot phase of a pandemic. By providing comparable data across countries, the monitor facilitates collective learning and strengthens preparedness at both national and supranational levels (de Vries et al., 2024).

While the PEPB monitor was initially developed with pandemic preparedness as its primary focus, behavioural readiness for pandemics substantially overlaps with preparedness for other types of disasters and emergencies (Mehra, Gorter & de Valk, 2024). Many of the behaviours and psychosocial determinants relevant to managing infectious disease outbreaks, such as trust in institutions, risk perception, social cohesion, health, health literacy, and household preparedness, also play an important role in preparedness for natural, technological, and human-made disasters. Recent work has emphasised the importance of adopting an all-hazards perspective to preparedness, recognising that populations are increasingly exposed to compound and cascading risks that extend beyond

infectious disease threats alone (Penta et al., 2021; Peleg et al., 2021). By situating pandemic preparedness within a broader disaster preparedness framework, the PEPB monitor aligns with this perspective and increases its relevance for integrated emergency management. This broader framing supports the use of the monitor not only to inform pandemic-specific policies but also to strengthen general societal resilience and preparedness across a range of potential emergency scenarios.

Theoretical underpinnings

Our study follows on from the recently proposed conceptual framework by Kroese et al. (under review), which emphasises pandemic preparedness as multi-layered and time-dependent, with attention to behaviours and their determinants across different phases of the emergency management cycle. Here we set out to operationalise an individual-level monitor that reflects this model. In the context of pandemic preparedness policy development, we also acknowledge the need to assess generic and behaviour-specific determinants and to account for the dynamic requirements of various types of possible outbreaks, which will require differential behaviour change approaches (Kroese et al., under review). Based on its wide recognition in academia, policy and practice and situational adaptability (Byrne-Davis et al., 2022; Ruggeri et al., 2024), we opted to use the COM-B model (Michie, van Stralen, & West, 2011), which conceptualises behaviour as a function of Capability, Opportunity, and Motivation.

In light of the framework, we focus on the PEPB monitor's potential to strengthen individual preparedness in light of the multiple levels of the socioecological model (Bronfenbrenner, 1979; McLeroy et al., 1988**)**. At the individual level, the monitor identifies behavioural determinants and capabilities that support infection prevention and emergency readiness (e.g. vaccination confidence, hand hygiene and health literacy). At the community and organisational levels, it assesses structural barriers and inequalities, such as social cohesion and equitable access to resources (Aldrich & Meyer, 2015). At the policy level, the monitor provides insights into systemic factors, including trust in institutions and citizens' expectations of government responsibilities.

Our study investigated the measurement properties and findings from the PEPB survey and integrates a range of constructs derived from previously validated instruments, ensuring theoretical and empirical robustness.

The Current Study

The aim of this paper is to introduce the PEPB monitor as a standardised, cross-nationally applicable survey for assessing pandemic preparedness from a behavioural perspective. Specifically, we describe the PEPB monitor and design, present its measurement properties, and thereby provide a methodological foundation for wider implementation with the aim of facilitating its adoption in other countries.

Methods

Data

The analysis includes PEPB data collected in March 2024 for four countries: The Netherlands, Spain, Ireland, and Slovenia. Each wave includes a representative sample of at least 1000 respondents from each country. The survey questions were developed in Dutch, Spanish, English, and Slovenian using a translation-backtranslation procedure to ensure the comparability of the findings.

In the first round, the survey was conducted among respondents from existing population research panels. In the Netherlands, panelists were recruited through probability sampling, while in the other countries recruitment was through online self-selection. To improve sample representativeness of the countries' population, panels used target quotas based on gender, age, educational level (feasible only in Spain, Netherlands and Ireland), and residential regions.

Measures

Various blocks of questions have been developed to aid individual preparations for public health and disaster scenarios. Given that the PEPB monitor was initially developed from a perspective of pandemic preparedness, and that the most likely outbreak scenario in a future pandemic is due to respiratory infection (Salmanton-García et al., 2024), the present study focuses on behaviours relevant to airborne transmission, such as hygiene practices and vaccination.

To determine the constructs to include, we completed a systematic exercise based on outbreak scenarios (RIVM, 2026c) and data about which behaviours (i.e. social isolation, social distancing, vaccination, test, trace and isolate, hand washing, mask wearing; Flaxman et al., 2020; Brauner et al., 2021; Talic et al., 2021) are important to manage the spread of a pandemic-scale respiratory infectious disease outbreak. Additionally, we reviewed behaviour that applied to multi-hazard preparedness (Boylan & Lawrence, 2020; European Commission, 2024; NCTV, 2024; Osman & Altıntaş, 2023). We selected the behaviours i) for which policy can be developed in a cold phase, ii) that were modifiable in the context of an intervention, iii) that were not easily changeable during hot phases, iv) that were not associated with demonstrable negative spillover effects (Dolan & Galizzi, 2018). For each behaviour, we assessed, based on the relevant literature (Betsch et al., 2020; Bish & Michie, 2010; Bussemakers et al., 2023; Devine et al., 2021; Freeman et al., 2022; Osman & Altıntaş, 2023; Paton, 2019; Van Bavel et al., 2020), which generic psychosocial construct may influence the selected behaviours (e.g., trust in institutions, social cohesion, conspiracy thinking). Finally, we incorporated factors that allowed us to differentiate between population subgroups (gender, level of education, physical and mental health). With an initial list of constructs, experts from various disciplines were invited to suggest the removal or addition of other constructs. These concerned infectious disease specialists, medical professionals, and behavioural scientists from national (Ireland, Spain, Slovenia, Sweden, Slovakia) and supranational institutes (JRC, WHO, ECDC) who had engaged with behavioural science monitoring in the COVID-19 pandemic (De Bruin et al., 2022; Rodríguez-Blázquez et al., 2021; Rehberger et al., 2021; WHO, 2020).

Following this process, the PEPB monitor included blocks for (1) sociodemographic characteristics, (2) outcomes, (3) behaviour, (4) capability, (5) opportunity, and (6) motivation. All included measures were validated tools or items adapted from existing research, (except for perceived financial health, perceived preparedness, and specific hygiene behaviours) and can be found in the PEPB User Guide (RIVM, 2026c).

Sociodemographic characteristics

Sociodemographic characteristics included gender, age, education level (low/middle/high), having a migration background (either themselves or their parents were born abroad), living alone (yes/no), urbanisation (rural/suburban/urban area), and region (Ireland: (1) Border and Midlands, (2) East, (3) South, (4) West; Netherlands: (1) North, (2) East, (3) West, (4) South; Slovenia: (1) Central: Zasavska, Posavska, Osrednjeslovenska, (2) East: Pomurska,

Podravska, Koroska, Savinjska, (3) South: Jugovzhodna Slovenija, Primorsko-notranjska, (4) West: Gorenjska, Goriska, Obalno-kraska; Spain: (1) East, (2) Madrid and Central, (3) North-West and North-East, (4) South and Canary Islands).

Outcomes

In the outcomes block, we measured general health, financial health, mental health and perceived preparedness

General Health. General health was measured with one question on an individual's rating of their own overall current health, using a visual 1 - 100 scale (EuroQol Research Foundation, 2019). A score of 60 or higher is classified as good general health.

Financial health. Financial health was measured with a question on perceived financial situation: 'How is your financial situation?' (1 = You are having problems making ends meet, 2 = You are getting by but have to be careful, 3 = Things are all right, 4 = You are doing well). Answers 3 and 4 are classified as good financial health.

Mental health. This was measured with the Mental Health Inventory (MHI-5; Berwick et al., 1991). A score under 60 is classified as mentally unhealthy.

Perceived preparedness. Perceived preparedness for a pandemic was measured with newly developed questions: 'If a lockdown were imposed next month because of the spread of a new virus (variant), to what extent would you feel [you/your employer/your government] are prepared for this?' (1 = Not at all prepared, 2 = Not prepared, 3 = Neutral, 4 = Well prepared, 5 = Very well prepared). Answers 4 and 5 are classified as feeling prepared.

Behaviour

In the behavioural block, we measured hygiene behaviours, social distancing (staying home when sick, and physical contact in case of illness). We also measured household preparedness behaviours.

Hygiene behaviours. We measured hygiene behaviours relevant to preventing the spread of infectious diseases, such as hand washing behaviour in the past seven days in five specific situations (after coughing, sneezing or blowing your nose; before preparing or eating food; after using the toilet; after cleaning your house; when coming back home; 0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Often, 4 = Always, 5 = Not applicable). We also asked how often participants coughed or sneezed in their elbow instead of their hand in the past seven days when they had to cough or sneeze (0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Often, 4 = Always, 5 = Not applicable - they did not have to cough and/or sneeze). For these items, the answers 'often' and 'always' were coded as performing this behaviour most of the time. These items were taken from the Dutch COVID-19 Behaviour monitor (Bussemakers et al., 2023).

Staying home when sick. To determine whether someone stayed home when feeling sick, we first asked participants whether they currently or in the past four weeks had any symptoms (Cold symptoms (such as nasal cold, runny nose, sneezing, sore throat), coughing, shortness of breath, increased temperature or fever, cold shivers, muscle and/or body aches) and whether they felt sick when they had these symptoms (yes / a little / no / I do not know). If they felt (a little) sick, we asked whether they went outside (For (medical) assistance, to run errands, to work or go to school/training, to get some fresh air or walk the dog, to go to a restaurant/bar or a cultural venue (cinema, theatre), to visit family or friends, for another reason). If participants did not go outside, or only went outside for medical

assistance, we coded them as ‘stayed home while feeling sick’. These items were taken from the Dutch COVID-19 Behaviour monitor (Bussemakers et al., 2023).

Social distancing. We also asked whether a participant had physical contact yesterday with someone (‘Did you have physical contact with others yesterday (excluding people you live with and excluding virtual contacts)?’; yes/no; RIVM, 2026b).

Household preparedness. We measured household preparedness behaviours regarding specific actions taken to be prepared for a pandemic or disaster (European Commission, 2024). Four items relate to preparing your home (‘Have a 3-day emergency supply stock of water for cooking and hygiene’, ‘Have a first aid kit at home’, and ‘Have a supply of face covers, disinfectant, and soap’) and one item relate to general readiness (‘Receive public warning messages (i.e. by signing up for alerts from authorities, if needed)’). Every item was answered with yes or no, and the item regarding receiving public warning messages included a ‘do not know / not applicable’ answer option. Having answered ‘yes’ to four or all five items was coded as ‘good household preparedness’.

Capability

Under capability, we measured health literacy and resilience. Additionally, outcome measures could also be placed under capability (physical and mental health) in certain models.

Health literacy. Health literacy was measured with the 6-item version of the HLS-EU-Q, for example ‘how easy would you say it is for you to judge if the information on health risks in the media is reliable?’ (1 = Very difficult, 2 = Difficult, 3 = Easy, 4 = Very easy, 5 = Don’t know; Sørensen et al., 2013). An average score of 3 or higher was coded as sufficient health literacy, a score between 2 and 3 was coded as problematic health literacy, and a score of 2 or lower was coded as inadequate health literacy (Pelikan et al., 2014).

Resilience. Resilience was measured with the 3-item brief resilience scale, for example ‘It does not take me long to recover from a stressful event’ (1 = Strongly Disagree to 5 = Strongly Agree; Smith et al., 2008). An average score of 3.5 or higher was coded as high resilience.

Opportunity

Under opportunity, we measure unmet healthcare needs, social support and social cohesion.

Unmet healthcare needs. Unmet healthcare needs was measured with the need (‘Was there any time during the last 12 months when you really needed a medical examination or treatment (excluding dental) for yourself?’ ; yes/no) and availability of healthcare, (‘Did you have a medical examination or treatment each time you really needed one?’; yes/no) with items adapted from the European Union Statistics on Income and Living Conditions (EU-SILC; Eurostat, 2026).

Social support. Social support was measured with three items: the number of people someone is close with, sense of interest or concern from other people, and relationship to neighbours (Dalgard et al., 2006). Responses were provided on a Likert scale of 1 to 5.

Social cohesion. To measure social cohesion we asked participants’ perceived connectedness with their country, region, and neighbourhood, similar to the Inclusion of Other in the Self Scale (Aron et al., 1992), by selecting one of seven pairs of increasingly overlapping circles. An average score of 4.5 or higher was coded as high social cohesion.

Motivation

Under motivation we measure trust in institutions, vaccine confidence, conspiracy beliefs and risk perception.

Trust in institutions. Trust in institutions was measured with three factors[1] (trust in politics and government, trust in national bodies and institutions, and trust in international institutions) based on 14 items adapted from the European Social Survey (2021) on a scale from 0 (no trust at all) to 10 (complete trust). High trust was coded as scoring 7 or higher per institute, and 7.5 or higher per factor.

Vaccine confidence. Vaccine confidence was measured with the 4 items of the Vaccine Confidence Index, for example 'Vaccines are safe' (1 = Strongly disagree to 5 = Strongly agree; Vaccine Confidence Project (VCP), De Figueiredo, 2020) and an additional item 'Vaccines are important for adults to get'. An average score of 3.5 or higher was coded as feeling confident about vaccines.

Conspiracy beliefs Conspiracy beliefs were measured with the 5-item Conspiracy Mentality Scale, for example 'I think that many very important things happen in the world, which the public is never informed about' (1 = Strongly Disagree to 5 = Strongly Agree; Bruder et al., 2013). An average score of 3.5 or higher was coded as endorsing conspiracy beliefs.

Risk perception Risk perception was measured with the probability and severity of five different situations (a man-made disaster, a highly contagious disease outbreak, a natural disaster, a terrorist attack, an armed conflict; European Commission, 2024). For probability, we asked 'How likely do you think the following disasters are to occur in your immediate region within the next five years?' (1 = Very unlikely, 2 = Quite unlikely, 3 = Somewhat unlikely, 4 = Somewhat likely, 5 = Quite likely, 6 = Very likely, 7 = Don't know). An average score of 4.5 or higher was coded as likely. For severity, we asked 'How personally affected (emotionally and practically) would you be if the following disaster happens in your immediate region?' (1 = Not affected, 2 = Mildly affected, 3 = Moderately affected, 4 = Severely affected, 5 = Don't know). An average score of 3.5 or higher was coded as personally affected.

Find the full survey in the User Guide (RIVM, 2026b).

Analysis

Survey weights

To improve the representativeness of the four samples, we applied *inverse probability weighting* (IPW). To do this, we combined the PEPB data with individual-level data from the European Social Survey (ESS): a high-quality probability-based dataset of survey responses on public attitudes, beliefs, and behaviours (ESS ERIC, 2024). Using logistic regression, we calculated respondents' probability of participating in the ESS based on a set of variables available in both the PEPB and ESS datasets. For each PEPB respondent, the inverse of this probability defined the primary weight. The primary weights were adjusted to match the countries' gender, age, region, and educational level distribution within the population using raking. The purpose of this weighting procedure was to align the PEPB sample

[1] The PEPB survey includes 14 items on trust in institutions. To reduce the number of variables to accommodate the validity analyses, we constructed three institutional trust subscales based on an Exploratory Factor Analysis across the countries, including (1) trust in politics and government (political parties, politicians, and the government), (2) trust in national bodies and institutions (police, science, healthcare, and general practitioners), and (3) trust in international institutions (European institutions, United Nations, and Worls Health Organization). The remaining institutional trust items (trust in the law, media, ministry of health, the national public health agency) varied in their relation with the underlying factors across countries, and hence were not part of the three subscales (and also excluded in the analyses related to validity).

characteristics more closely with those of probability samples, thereby reducing sampling and coverage bias and reducing differences in sampling designs. The ESS dataset was selected as the reference probability sample due to its overlap with the PEPB survey in terms of country coverage and fieldwork. Details on how the IPW weights were calculated are available on OSF (osf.io/56shq).

Measurement properties

Validity of the measures was examined using Multigroup Structural Equation Modelling (MSEM), with groups defined by country. Specifically, for each country, we specified a Pearson correlation matrix of all multi-item and single-item measures. Multi-item constructs were defined as latent variables using Confirmatory Factor Analysis (CFA). Measures that included a 'not applicable'-option or that were not assessed in all four countries were excluded from the validation analyses[2]. This was necessary because recoding 'not applicable' to missing would yield non-random missing data, leading to biased estimates in our MSEM model. After this exclusion, only validated or existing measures were included in the model, which warrants our confirmatory (rather than exploratory) approach. The correlation matrix of all selected multi-item latent and single-item measures was used for all analyses related to examining measurement properties.

Structural validity refers to the quality of the factor structure of the latent variables. It was considered adequate when the multigroup model showed good model fit in terms of Comparative Fit Index (CFI: ≥ .900), Tucker-Lewis Index (TLI: ≥ .900), Root Mean Square Error of Approximation (RMSEA: ≤ .080), and Standardised Root Mean Square Residual (SRMR: ≤ 0.100) (Hu & Bentler, 1999). In addition, adequate structural validity requires standardised item factor loadings of ≥.40 (Howard, 2016). Additionally, we examined whether results from the CFA were measurement invariant across countries by analysing whether applying equality constraints to the factor loadings (i.e., metric invariance) and intercepts/thresholds (i.e., scalar invariance) deteriorated model fit. This was the case when CFI or TLI decreased with ≥ .010 and RMSEA increased with ≥ 0.015 (Chen, 2007; Cheung & Rensvold, 2002). Modification indices were consulted to identify sources of misfit within our model. Constructs with invariant factor loadings and intercepts/thresholds allow for valid cross-national comparisons of correlations and means, respectively.

Convergent validity examines the extent to which constructs that are theoretically related are also observed as such. It was considered adequate when the direction of the correlations between measures corresponded to those reported in other research. Correlations of 0.10, 0.30 and 0.50 were considered small, moderate, and large, respectively. Only correlations that were pre-registered for assessment of convergent validity were evaluated on their convergent validity (osf.io/56shq). Based on previous research, we expected that a higher risk perception of disasters would be associated with lower perceived pandemic preparedness (Feng & Ji, 2014), stronger household preparedness with higher perceived pandemic preparedness (DeBastiani et al., 2015), higher age with lower general health (König et al., 2009), medical risk with lower general health (Kontodimopoulos et al., 2008), higher educational level with stronger financial health (Assari et al., 2024), higher

[2] These excluded measures were perceived pandemic preparedness of the employer, unmet healthcare needs, and several behaviors relevant to preventing the spread of infectious diseases, including the use of hand sanitizer, handwashing, coughing and sneezing in elbow, staying at home while feeling sick, contact with people that are vulnerable to infections (while being sick), working from home.

general health with higher mental health (Mao et al., 2024), stronger social support with stronger social cohesion (Dupuis et al.,2017), higher educational level with stronger health literacy (Sørensen et al., 2015), stronger vaccine confidence with stronger institutional trust (Allington et al., 2021), stronger conspiracy beliefs with weaker vaccine confidence (Allington et al., 2021), and stronger conspiracy beliefs with weaker institutional trust (Allington et al., 2021; Martinez et al., 2022).

Furthermore, to assess whether correlations were comparable across countries, we compared the model fit of a model with different versus equal covariances, again using changes in CFI, TLI, and RMSEA, and inspected sources of misfit using modification indices.

Internal consistency indicates how closely related items on a scale are to each other and as such, reliably measure one underlying concept. It was examined using Cronbach's alpha based on the Pearson correlation matrix, with values > .70 indicating good reliability.

Cross-national comparisons

We investigated whether country-specific values of the PEPB measures differed significantly from the grand mean in the weighted pooled sample ($p < 0.05$). To facilitate interpretation in terms of proportions, all measures were dichotomised using recommended cut-off values where available. Differences from the grand mean were examined using linear contrast tests based on logistic regression models, with the dichotomised outcome predicted by country.

Examples of survey use: handwashing, social cohesion and trust in institutions

To illustrate how the collected data can be used to advance preparedness across multiple levels of the socioecological model, we conducted three regression analyses. Each focused on constructs that proxy for effects on individual-level behaviour, stemming from factors at the individual, community, and governmental levels. For the individual level (Model 1), we analysed predictors of (individual) behaviour of handwashing. For the community level (Model 2), we analysed predictors of social cohesion. And for the institutional level, we analysed predictors of general trust in institutions (Model 3). In every regression model, we added demographic variables (age, gender, education, migrant background, urbanisation, medical risk group, household members) in the first step, and relevant psychosocial variables (Model 1: general trust in institutions, health literacy, risk perception of disasters; Model 2: general trust in institutions and social support; Model 3: health literacy, conspiracy thinking and risk perception of disasters) in the second step.

Technical details

All analyses were conducted in R version 4.4.1 (R Core Team, 2024). Analyses were conducted using the computed IPW survey weights. Prior to conducting the analyses of the present study, the analysis plan was established and published. Scripts for all analyses and the analysis plan are available on OSF (osf.io/56shq). Deviations from this analysis plan include (1) excluding handwashing items and use of hand sanitizer items from the validation analysis, (2) extending the convergent validity analysis with correlations between all measures (except a few excluded ones[1]) instead of correlations between a selection of measures, (3) removing testing associations between specific demographics and specific constructs from the convergent validity analysis, (4) moving demographic differences in a selection of measures to the supplemental material instead of reporting them in the main paper, as well as adding other (unregistered) associations between demographics and measures to this supplemental material, (5) selecting three out of the seven registered

regression models for the survey use examples, (6) adding migration background as independent variable in the survey use example regression models.

Results

Sample description

Table 1 shows the sample distribution by country before and after applying IPW- and raking-based weights. Lower and higher sample sizes in the unweighted samples relative to the weighted samples indicate under- and overrepresented groups, respectively. The most underrepresented groups were people with lower levels of education in Slovenia, people aged 70 or older in Ireland and Spain, people residing in rural and suburban areas in Spain, and people residing in Central Slovenia.

Table 1 Sample characteristics PEPB survey (March 2024)

	Ireland				Netherlands				Slovenia				Spain			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Female	581	58.04	511	51.04	519	52.00	510	51.12	786	51.64	762	50.10	574	52.71	561	51.54
Male	420	41.96	490	48.96	479	48.00	488	48.88	736	48.36	760	49.90	515	47.29	528	48.46
Age <25 years	143	14.19	118	11.71	61	6.10	118	11.76	134	8.80	123	8.06	80	7.23	96	8.72
Age 25-39	317	31.45	256	25.42	194	19.40	241	24.14	389	25.56	333	21.87	306	27.67	234	21.15
Age 40-54	335	33.23	288	28.55	207	20.70	237	23.72	466	30.62	414	27.21	436	39.42	329	29.75
Age 55-69	156	15.48	212	21.01	299	29.90	232	23.17	450	29.57	523	34.36	216	19.53	312	28.19
Age 70+	57	5.65	134	13.31	239	23.90	172	17.21	83	5.45	129	8.50	68	6.15	135	12.19
High educational level	474	47.02	428	42.43	431	43.19	351	35.13	708	46.52	473	31.08	369	33.36	347	31.41
Medium educational level	394	39.09	354	35.10	355	35.57	367	36.75	780	51.25	801	52.64	240	21.70	232	20.99
Low educational level	140	13.89	226	22.47	212	21.24	281	28.12	34	2.23	248	16.28	497	44.94	526	47.60
No migrant background	660	65.48	750	74.37	761	77.97	763	78.15	1252	82.26	1223	80.32	993	89.78	935	84.51
Migrant background	348	34.52	258	25.63	215	22.03	213	21.85	270	17.74	299	19.68	113	10.22	171	15.49
Does not live alone	847	84.03	853	84.62	751	75.10	792	79.15	1344	88.30	1290	84.77	956	86.44	961	86.87
Lives alone	161	15.97	155	15.38	249	24.90	208	20.85	178	11.70	232	15.23	150	13.56	145	13.13
Lives in a rural area	393	38.99	494	49.05	347	35.44	422	43.11	637	41.85	801	52.61	190	17.18	357	32.31
Lives in a suburban area	340	33.73	356	35.32	330	33.71	329	33.58	333	21.88	370	24.31	176	15.91	310	27.99
Lives in an urban area	275	27.28	158	15.63	302	30.85	228	23.31	552	36.27	351	23.09	740	66.91	439	39.70
Region1*	153	15.18	142	14.04	94	9.40	101	10.12	254	16.69	493	32.38	312	28.21	322	29.09
Region2*	490	48.61	438	43.43	230	23.00	207	20.73	546	35.87	564	37.06	291	26.31	288	26.05
Region3*	188	18.65	235	23.35	426	42.60	478	47.81	505	33.18	142	9.34	211	19.08	207	18.73
Region4*	177	17.56	193	19.18	250	25.00	213	21.34	217	14.26	323	21.22	292	26.40	289	26.13

*Ireland: (1) Border and Midlands, (2) East, (3) South, (4) West; Netherlands: (1) North, (2) East, (3) West, (4) South; Slovenia: (1) Central: Zasavska, Posavska, Osrednjeslovenska, (2) East: Pomurska, Podravska, Koroska, Savinjska, (3) South: Jugovzhodna Slovenija, Primorsko-notranjska, (4) West: Gorenjska, Goriska,Obalno-kraska; Spain: (1) East, (2) Madrid and Central, (3) North-West and North-East, (4) South and Canary Islands. In Slovenia regions were based on https://ec.europa.eu/eurostat/web/nuts

Measurement properties

Structural validity and internal consistency

The multigroup SEM with free factor loadings and free intercepts/thresholds showed an acceptable overall model fit, with good RMSEA and SRMR values, but CFI and TLI were slightly below the threshold for good model fit (Table 2: Model 1). Although allowing for some cross-loadings and correlated residuals could improve the CFI and TLI, these adjustments

were not implemented to maintain a parsimonious model and to focus on testing loading and intercept/threshold invariance. Constraining factor loadings to be equal across countries barely affected model fit, supporting metric invariance (Table 2: model 2). This suggests that we can make valid cross-national comparisons of correlations between all constructs.

However, constraining item intercepts and thresholds led to poorer fit (Table 3: model 3), thus rejecting scalar invariance. Non-invariance was mainly driven by items assessing mental health and two aspects of risk perception: perceived likelihood of disaster occurrence, and perceived severity of disaster consequences (Table 3: model 4). This pattern suggests that respondents in different countries systematically interpret or use the response scales for these constructs differently, leading to structural differences in reporting rather than true differences in the underlying latent traits. This means that comparisons across countries on mental health and disaster risk perception (i.e., likelihood and severity) should be interpreted with caution.

All constructs had items with high factor loadings, except for health literacy in Slovenia, which included one (out of six) item with a factor loading below .4 (see Table 3). Also, Cronbach's alpha for health literacy was somewhat low in Slovenia (.69). In all four countries, the internal reliability of items from resilience and social support was just below the threshold for good internal consistency (Cronbach's alpha < 0.70). In the Netherlands, the internal consistency of household preparedness was almost adequate (.66). All other constructs showed good to excellent internal consistency.

[see Table 2 at end of paper]

Table 3 CFA standardised factor loadings (structural validity) and Cronbach's alpha (internal consistency), by country

Latent variable with its items	Ireland	Netherlands	Slovenia	Spain
Mental health	(α = 0.84)	(α = 0.86)	(α = 0.87)	(α = 0.82)
Feels nervous (r)	0.70	0.79	0.75	0.67
Feels so down, nothing could cheer up (r)	0.78	0.90	0.85	0.67
Feels calm and relaxed	0.63	0.56	0.64	0.64
Feels sad and depressed (r)	0.75	0.79	0.77	0.64
Feels happy	0.70	0.60	0.68	0.67
Resilience	(α = 0.58)	(α = 0.67)	(α = 0.68)	(α = 0.68)
Reports hard time making it through stressful events (r)	0.67	0.77	0.78	0.77
Does not take long to recover from a stressful event	0.43	0.49	0.50	0.50
Finds it hard to snap back when something bad happens (r)	0.53	0.65	0.63	0.66
Social cohesion	(α = 0.83)	(α = 0.80)	(α = 0.86)	(α = 0.82)
Feels connection with the country	0.90	1.00	0.93	0.87
Feels connection with the province	0.77	0.79	0.81	0.73
Feels connection with the neighbourhood	0.67	0.66	0.71	0.71
Social support	(α = 0.61)	(α = 0.64)	(α = 0.61)	(α = 0.59)
Has people close to count on	0.51	0.45	0.52	0.48
People show interest and concern	0.69	0.75	0.71	0.67
Easily gets practical help from neighbours	0.55	0.58	0.54	0.54
Risk perception: perceived likelihood that disaster occurs	(α = 0.88)	(α = 0.87)	(α = 0.81)	(α = 0.85)
Likelihood of man-made disasters	0.78	0.72	0.61	0.66
Likelihood of highly contagious disease outbreak	0.65	0.67	0.53	0.62

Likelihood of natural disaster	0.70	0.66	0.63	0.67
Likelihood of terrorist attack	0.83	0.87	0.73	0.83
Likelihood of armed conflict	0.86	0.85	0.78	0.82
Risk perception: personal impact of disasters	(α = 0.87)	(α = 0.86)	(α = 0.85)	(α = 0.83)
Severity of man-made disasters	0.73	0.63	0.60	0.64
Severity of highly contagious disease outbreak	0.84	0.73	0.63	0.74
Severity of natural disaster	0.75	0.74	0.73	0.74
Severity of terrorist attack	0.72	0.77	0.77	0.73
Severity of armed conflict	0.70	0.79	0.84	0.67
Household preparedness	(α = 0.78)	(α = 0.66)	(α = 0.77)	(α = 0.82)
Has a 3-day stock of food, drinks, and meds and home	0.68	0.60	0.66	0.71
Has a first aid kit at home	0.63	0.56	0.62	0.66
Has a 3-day stock of water at home	0.55	0.48	0.53	0.57
Has face masks, sanitizer, and soap at home	0.83	0.73	0.81	0.87
Receives government alerts	0.62	0.55	0.61	0.65
Vaccine confidence	(a = 0.92)	(a = 0.93)	(a = 0.93)	(a = 0.93)
Finds vaccines important for children	0.76	0.84	0.79	0.71
Finds vaccines important for adults	0.80	0.79	0.78	0.84
Finds vaccines safe	0.89	0.89	0.90	0.89
Finds vaccines effective	0.86	0.87	0.90	0.87
Finds vaccine compatible with own beliefs	0.90	0.85	0.88	0.91
Trust in politics	(a = 0.93)	(a = 0.96)	(a = 0.91)	(a = 0.89)
Trust in the government	0.96	0.99	0.82	0.87
Trust in politicians	0.86	0.91	0.89	0.83
Trust in political parties	0.86	0.89	0.91	0.82
Trust in national institutions	(a = 0.82)	(a = 0.92)	(a = 0.85)	(a = 0.84)
Trust in the police	0.71	0.82	0.72	0.67
Trust in science	0.76	0.83	0.82	0.81
Trust in healthcare	0.69	0.88	0.79	0.79
Trust in medical doctors	0.70	0.87	0.72	0.75
Trust in international institutions	(a = 0.93)	(a = 0.92)	(a = 0.93)	(a = 0.91)
Trust in European institutions	0.89	0.82	0.88	0.85
Trust in the United Nations	0.86	0.83	0.88	0.85
Trust in the World Health Organization	0.94	0.96	0.93	0.93
Conspiracy beliefs	(a = 0.81)	(a = 0.87)	(a = 0.81)	(a = 0.81)
Public never informed about many very important things that happen in the world	0.60	0.68	0.65	0.60
Politicians do not tell true motives for their decisions	0.67	0.73	0.75	0.62
Government agencies closely monitor all citizens	0.61	0.65	0.51	0.62
Events which seemingly lack connection are often the result of secret activities	0.74	0.79	0.69	0.77
Secret organizations greatly influence political decisions	0.75	0.87	0.69	0.77
Health literacy	(a = 0.83)	(a = 0.86)	(a = 0.69)	(a = 0.80)
Able to judge when a second opinion from another doctor is necessary	0.49	0.46	0.33	0.47
Able to use information from a doctor to make decisions about illness	0.69	0.67	0.55	0.65
Able to find information to manage mental health problems	0.72	0.77	0.58	0.69

Able to judge if information on health risks in the media is reliable	0.66	0.62	0.47	0.58
Able to find out about activities that are good for mental wellbeing	0.73	0.86	0.58	0.70
Understands information in the media on how to get healthier	0.72	0.77	0.54	0.69

a = Cronbach's alpha; r = reversed item.

Notes.

Standardised factor loadings computed while imposing equal unstandardised factor loadings across countries (i.e., metric invariance; Table 2 model 2).

All factor loadings are significant at $p < 0.001$

Convergent validity

Figures 1a-d show the correlations between the multi- and single-item constructs in the four countries when imposing metric invariance (Table 2, model 2). In all four countries, as expected, moderate to strong positive correlation coefficients were observed between mental health and resilience (range: .64 - .78), trust in national institutions (police, science, healthcare system, doctors) and vaccine confidence (.51 - .60), trust in international institutions (European institutions, United Nations; UN, World Health Organization; WHO) and vaccine confidence (.25 - .53), mental health and general health (.30-.48), and social support and social cohesion (.30 - .35). We observed small to moderate positive correlation coefficients between individual perceived preparedness and household preparedness (.25 - .35) in all countries. Small to moderate negative correlation between conspiracy beliefs and trust in international institutions (-.08 - -.48) and conspiracy beliefs and trust in politics (national government, politicians, political parties) (-.28 - -.40) were found in all countries.

To identify inconsistencies in correlations between countries, we constrained the covariances between all constructs to be equal across countries. This constrained model showed poorer fit (Table 2, model 5) than the model with all free covariances (Table 2, model 2). Inspection of modification indices showed that the constrained model would yield substantial improvement in model fit when freeing the covariances involving conspiracy and vaccine confidence. After adjusting the model accordingly (Table 2, model 6), in Spain, conspiracy thinking was positively correlated with trust in national institutions and vaccine confidence, while in the other three countries these correlations were negative (in line with the literature). Also, in Spain, there was virtually no correlation between vaccine confidence and trust in politics, while in the other countries, there was a moderate to strong positive correlation (Rodríguez-Blázquez et al. 2021; Santos-Ribeiro et al. 2025). After allowing the covariances involving conspiracy and vaccine confidence to vary across countries, while all other covariances were held equal across countries, the model fit was comparable to the model with all free covariances (Table 2, models 2 and 6). This suggests that other observed cross-national differences in correlations (Figure 1) were not substantial.

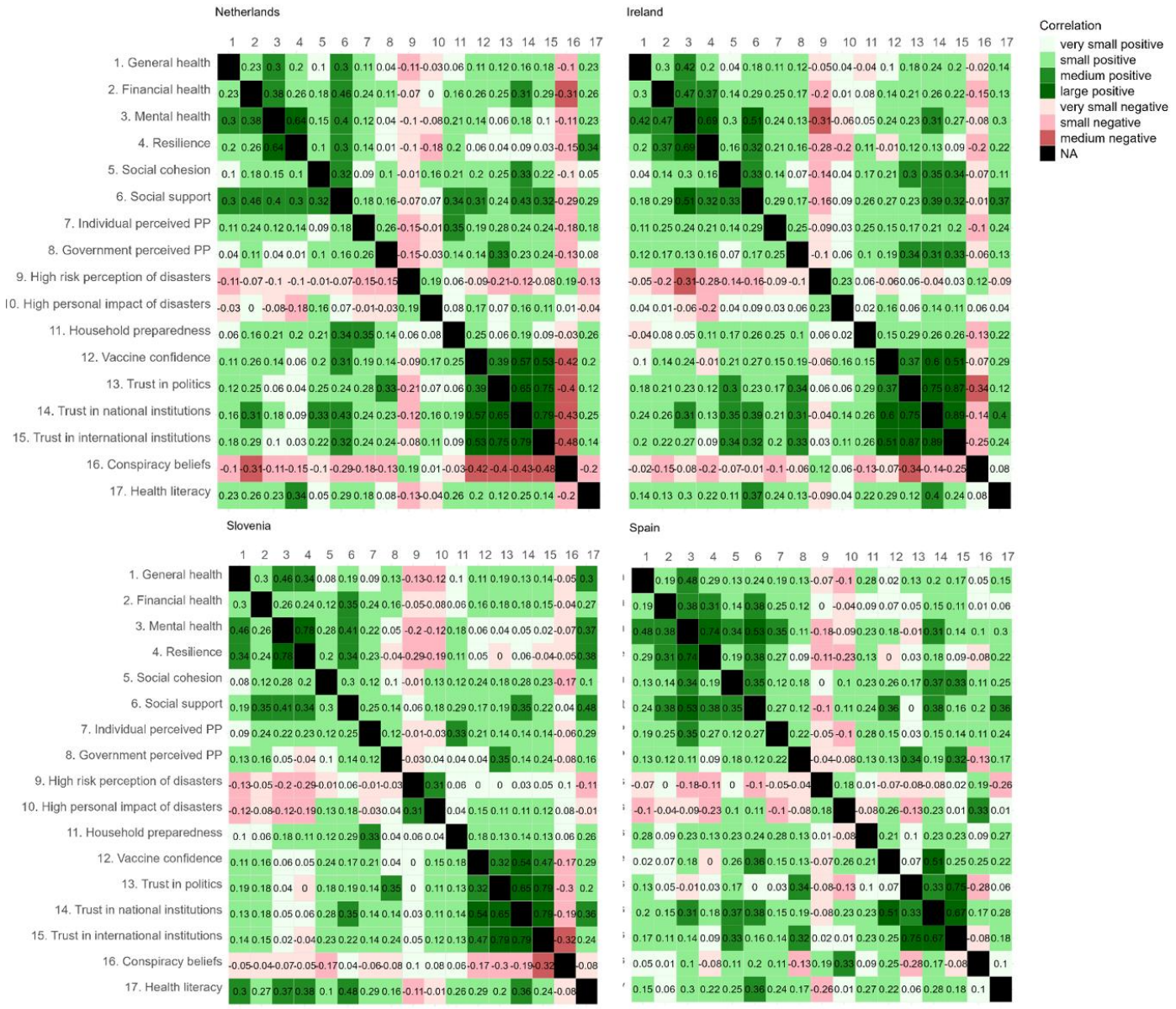


Figure 1a-d: Heat map of correlations between the PEPB measures in the Netherlands (top left), Ireland (top right), Slovenia (bottom left) and Spain (bottom right)

Cross-national comparisons in (determinants of) health outcomes, health behaviours, and preparedness behaviours

Table 4 shows the percentages of all measures by country. In general, respondents in Slovenia report adhering more to behaviours that prevent the spread of infectious diseases than people in other countries, particularly handwashing after coughing, sneezing, and nose blowing, and after entering the home. With regard to household disaster preparedness, Dutch people are generally less prepared than people from other countries, particularly in having a 3-day emergency water supply.

Large differences were found between countries for perceived financial health: in the Netherlands, the vast majority report that their financial situation is all right or that they are doing well, whereas in the other three countries, this is a minority. The Netherlands also scores more favourably on the other outcome measures (physical and mental health) relative to other countries.

Substantial differences in institutional trust were observed across countries. In Slovenia, trust in institutions was consistently lower than in other countries. Overall, respondents reported the highest levels of trust in doctors and science, while trust in politicians and political parties was consistently reported as the lowest.

Additional country differences were observed, though they were generally less substantial. Differences by gender, age, educational level, migrant background, and urbanisation degree within countries can be found on OSF osf.io/56shq).

[see Table 4 at end of paper]

Use case examples of the PEPB monitor to explain behaviour or psychosocial patterns

To assess possible uses of the PEPB in assessing individual, community and societal factors related to behavioural (handwashing) and psychosocial (trust and social cohesion) outcomes, we estimated three stepwise regression models including demographic and pre-registered psychosocial predictors (Supplementary material 2 for each model). The results show 1) substantial cross-national variation in the pattern of significant predictors and 2) overlapping patterns between countries.

Consistencies between countries for the outcome of handwashing include the effect of age (in two countries) and risk perception (in three countries): younger adults and those who think that effects of disasters are more severe are more likely to wash their hands. For the outcome of social cohesion we observe nearly the same pattern across all four countries: feeling more connected is predicted by being older (55+), seeing one's government as more trustworthy (trust in government) and feeling more supported by their neighbours (social support). For the outcome of trust in government, negative effect of conspiracy thinking (in three countries) and a positive effect of health literacy (in two countries) and risk perception (in two countries) show to be consistent. In other words, trust in government is higher for those who have lower levels of conspiracy thinking, are more likely to think that effects of disasters are severe and are more health literate.

We also observe country-specific effects. For example, in Spain those living alone are 15 times more likely to wash their hands than those in other subgroups. In Ireland, we observe the opposite: those living alone are less likely to wash their hands. In the Netherlands, health literacy is important: those who are more literate are 2.8 times more likely to wash their hands than those who are not. This is not the case in the other three countries. For social cohesion demographic effects vary strongly: In Slovenia women and those who live suburban report greater social cohesion than men and those who live in urban environments. In Spain lower social cohesion is predicted by living alone, and in the Netherlands by lower levels of education. Trust in government shows only two country-specific effects, also demographic: in Ireland those over 70 are 3.6 times as likely to trust the government relative to other age groups. In Spain, those who hold a migrant status are 3 times as likely, relative to those who are not.

Overall, preparedness-related attitudes and behaviours are shaped by a combination of shared psychosocial and demographic factors, with distinct supranationally and nationally robust patterns, stressing the importance of international comparison.

Discussion

Our study investigated the measurement properties and findings from the PEPB survey, designed to measure preparedness-related behaviours, their determinants, and self-reported health during a cold phase, and to capture changes during a hot phase of a pandemic. The PEPB survey integrated a range of constructs derived from previously validated instruments, ensuring theoretical and empirical robustness. In addition to outlining its measurement properties, this paper contributes to the evidence on pandemic preparedness behaviours by presenting empirical results across participating countries. Our analyses offer insight into key determinants of preparedness behaviours during a cold phase, behaviours relevant to likely outbreak scenarios, and associated health outcomes.

Summary of findings

With respect to instrument validation, we find that adequate structural validity of the multi-item measures was, for a large part, supported because (1) the model fit was generally good , (2) most constructs were measured using exclusively items with high factor loadings, and (3) factor loadings were approximately equal across countries, whereas some intercepts varied. The internal reliability of all included measures was adequate in all countries, except for resilience (all countries), social support (all countries), household preparedness (the Netherlands), and health literacy (Slovenia). These findings suggest that, although these constructs can be meaningfully analysed as latent variables, future iterations of the PEPB monitor may benefit from refining or expanding these item batteries to improve their psychometric performance.

Convergent validity was also largely supported, as most observed correlations were in the expected direction and of comparable magnitude to those reported in previous research. For example, the strong positive correlations between mental health and resilience, social support and social cohesion, and institutional trust and vaccine confidence are consistent with earlier studies on psychosocial resources, trust, and health behaviour in public health contexts (Dupuis et al., 2017; Allington et al., 2021). Similarly, the negative correlations between conspiracy beliefs and institutional trust or vaccine confidence align with established findings from the COVID-19 literature, which consistently show that conspiracy thinking undermines trust in authorities and acceptance of public health measures (Allington et al., 2021; Martínez et al., 2022; Lewandowsky et al., 2023). The magnitude of these associations was generally small to moderate, consistent with expectations for population-level survey data examining complex psychosocial determinants of behaviour.

We also observed a notable cross-national difference in correlation patterns. In Spain, conspiracy beliefs were positively associated with trust in national institutions and vaccine confidence, contrary to the literature and to the patterns observed in the other three countries. Given Spain's high trust in healthcare professionals and science and consistently high vaccination rates (Rodríguez-Blázquez et al., 2021), these items may reflect a different, context-specific form of institutional evaluation rather than conspiracy thinking. This finding suggests that the conspiracy scale may warrant reconsideration or adaptation for use in Spain and potentially in other cultural contexts.

Substantial cross-national differences were also observed at the descriptive level, particularly for perceived financial health, hygiene behaviours such as handwashing, household preparedness, and conspiracy beliefs. For example, Slovenian respondents reported consistently higher adherence to hygiene behaviours and higher levels of household preparedness, whereas Dutch respondents were less likely to report having a

three-day stock of water at home. Large differences in perceived financial health were observed between the Netherlands and the other countries. These findings illustrate that preparedness-related constructs and their determinants are highly context-dependent.

Finally, we illustrated PEPB monitor's practical utility through three use cases across a behavioural (hand washing) and two psychosocial outcomes (social cohesion and trust in institutions). These analyses demonstrated how PEPB data can be used to examine behavioural, social, and institutional determinants of pandemic and health emergency preparedness across countries. The regression models show that some predictors differed across national contexts, whilst others displayed consistent patterns, illustrating the importance of cross-national comparison to identify supranational and national policy drivers. At the individual level, age and risk perception were consistently associated with handwashing behaviour in three of the four countries. In social cohesion, community factors seemed to be more important than national differences, showing to be strongly predicted by both institutional trust and social support across all four countries. Across all countries aside from Spain, we also find that trust in institutions was systematically lower among respondents with stronger conspiracy beliefs and trust was higher among those with higher health literacy in most countries. This suggests that increasing health literacy may have positive spillover effects on institutional trust. Together, these use cases demonstrate how the PEPB monitor can support targeted analyses that identify context-specific leverage points for strengthening preparedness across multiple levels of the socioecological model.

Methodological Implications

The finding that factor loadings were invariant across countries implies that correlations between constructs can be reliably compared cross-nationally. This is a key prerequisite for using the PEPB monitor to examine relationships between behaviours, determinants, and outcomes in different national contexts. In contrast, scalar invariance was not supported for a few constructs, particularly mental health, and risk perception: perceived likelihood of disaster occurrence, and severity of disaster consequences. This implies that respondents in different countries with the same underlying level of these traits may systematically use response scales differently. As a result, observed mean differences for these constructs may not only reflect true differences but also differences in response styles, cultural norms, or item interpretation. This phenomenon is common in cross-national research and underscores the need for caution when interpreting country rankings or mean differences for these constructs (Meitinger et al., 2020).

The internal reliability of the resilience, social support, household pandemic preparedness, and health literacy items was not always sufficient. This implies that analysing these constructs as latent variables or factor scores is preferred over using mean or sum scores. Alternatively, future revisions of the survey may focus on improving these questions to enhance their measurement properties as constructs.

Policy implications

Next to methodological implications, our findings may be able to support policy in various capacities. For example, low trust in government and political institutions (if paired with [3]trust in science and healthcare workers[OBJ]) may represent a potential barrier to effective

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Notably, the Spanish case suggests that low trust in government does not necessarily translate into lower compliance or vaccination uptake when it is offset by consistently high trust in science and

pandemic preparedness, as institutional trust is a often a key determinant of compliance with public health recommendations and in some cases vaccination uptake (van der Weerd et al., 2011; Bargain & Aminjonov, 2020; Allington et al., 2021; OECD, 2017).

Similarly, patterns in hygiene behaviours and household preparedness suggest that preparedness during a cold phase may require active policy support (van Bavel et al., 2020; Betsch et al., 2020). Sustaining basic hygiene practices and encouraging household preparedness outside crisis periods may not only increase behavioural readiness and reduce delays in behavioural uptake during future outbreaks (Paton, 2019; Feng & Ji, 2014) but also prevent disease outbreaks (Curtis & Cairncross, 2003)

Kroese et al. (*under review*) highlights that behaviour is shaped by individual, social, and institutional factors operating at multiple levels of the socioecological model (Bronfenbrenner, 1979; McLeroy et al., 1988). Our use cases demonstrate that a wide range of research questions pertaining to individual, social, and institutional factors could be informed by our data. For example, the PEPB monitor can be used to identify determinants of household preparedness (Paton, 2019) to examine subgroup differences in preparedness by age, education, or migration background (Kohn et al., 2012), or to study how trust, health literacy, and social cohesion informs behavioural compliance (Bargain & Aminjonov, 2020). Future data collection will allow researchers to examine how preparedness evolves over time and how cold-phase preparedness predicts behavioural responses during hot phases (Bish & Michie, 2010).

Such research questions can directly inform policy. Identifying the determinants of household preparedness may help target communication campaigns at specific population subgroups (Betsch et al., 2020). Monitoring trust in institutions can provide early warning signals of declining legitimacy and cooperation capacity (Levi & Stoker, 2000; OECD, 2017). Tracking hygiene behaviours during cold phases may help assess whether preparedness fatigue or complacency is emerging (WHO, 2020; de Bruin et al., 2020). In this way, the PEPB monitor can support both preventive policy during cold phases and adaptive policy during hot phases (Boin et al., 2017).

Strengths and limitations

A key strength of this study is that the PEPB monitor was developed using a strong theoretical foundation, integrating established behavioural science frameworks with insights from public health preparedness research (Michie et al., 2011; van Bavel et al., 2020). Wherever possible, the survey builds on validated instruments widely used in prior research, thereby enhancing both the conceptual robustness and cross-study comparability of the measures (Sørensen et al., 2015; Allington et al., 2021). In addition, the development of the PEPB monitor was supported by an interdisciplinary network of scholars and practitioners, including behavioural scientists, public health researchers, and experts from national and supranational public health institutions. Interdisciplinary collaboration has been shown to strengthen the relevance and usability of preparedness research for policy and practice (Boin et al., 2017; OECD, 2017).

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healthcare professionals. Despite periods of low political trust, Spain achieved one of the highest COVID-19 vaccination rates in Europe, and adherence to preventive behaviours remained high. Empirical evidence shows that trust in scientific expertise and health workers has been persistently strong in Spain and was a key driver of both preventive behaviour and vaccine acceptance during the pandemic (Beca-Martínez et al., 2022a; Beca-Martínez et al., 2022b). This highlights the importance of distinguishing between trust in political institutions and trust in scientific and healthcare authorities when assessing determinants of pandemic preparedness and public health compliance.

Several limitations should also be acknowledged. First, sampling designs differed across participating countries. While the Netherlands relied on a probability-based household panel, data collection in the other countries used quota-based convenience panels. To mitigate differences in representativeness, IPW was applied using the European Social Survey as the reference, an approach shown to reduce sampling and coverage bias when high-quality probability samples are available (Kalton & Flores-Cervantes, 2003). Nevertheless, some residual bias may remain. Second, the representation of respondents with low educational attainment was limited in Slovenia, resulting in relatively large survey weights for this subgroup. Such high weights increase sampling variance and reduce the precision of subgroup estimates, thereby limiting the reliability of analyses by educational level in Slovenia (Kish, 1992; Valliant et al., 2018). Finally, as with most large-scale surveys, all measures were self-reported and may therefore be subject to recall and social desirability bias, particularly for socially normative behaviours such as hygiene practices (Althubaiti, 2016; Tourangeau & Yan, 2007).

Future research

Future studies can build on the PEPB monitor by extending data collection across additional countries and over multiple waves, enabling the assessment of temporal dynamics in preparedness behaviours and their determinants. Repeated data collections would allow examination of how preparedness during a non-crisis “cold” phase predicts behavioural responses and compliance ahead of an hot phase, as well as how these relationships evolve over time. Additionally, further work is needed to refine and validate specific survey components that show weaker measurement properties or context-dependent performance, such as conspiracy beliefs, resilience, and household preparedness. In addition, future studies could integrate PEPB data with policy, epidemiological, or administrative data to evaluate how changes in governance, communication strategies, or public health measures interact with behavioural preparedness. Together, these directions would strengthen the PEPB monitor as a tool for both scientific inquiry and evidence-informed preparedness policy.

We note also that our paper only validates the blocks developed for the March 2024 data collection. Since then, blocks have been developed on i) specific determinants of the above behaviours (self-efficacy, response efficacy, social norms and knowledge), ii) zoonotic outbreaks, iii) multi-hazard contexts (including flooding, war and power outage scenarios) and iv) general preparedness behaviours. We also deem v) vector-borne disease behaviours and vi) an experimental block as key components of future development efforts. Integrated data is not available at the time of preparing the manuscript, but the (English and Dutch) surveys and a user guide that details all the constructs used can be found online (RIVM, 2026c).

Conclusions

This study demonstrates that the Pandemic and Emergency Preparedness Behaviour (PEPB) monitor is a feasible and psychometrically sound tool for cross-national monitoring of preparedness behaviours and its determinants. Measures showed adequate validity, reliability, and metric invariance across four European countries, allowing for reliable assessments and meaningful comparison of associations. Scalar non-invariance highlights the need for caution when interpreting country-level mean differences.

Additionally, the PEPB monitor can be used as a tool to determine an empirical baseline for reference to allow for future pandemic and health emergency threat assessment. Substantial cross-national variation in preparedness-related behaviours and institutional trust indicates that behavioural readiness during non-crisis phases cannot be assumed. Continued implementation of the PEPB monitor over time across countries can support evidence-informed preparedness policy and strengthen societal resilience to future public health emergencies.

In sum, the PEPB allows for comparable data across different contexts enabling collective learning. In doing so, we aim to extend behavioural readiness and the understanding that resilience may differ across contexts and populations, thereby informing both national and supranational policy responses.

List of abbreviations

CFA – Confirmatory Factor Analysis
CFI – Comparative Fit Index
COM-B – Capability, Opportunity, Motivation–Behaviour model
COVID-19 – Coronavirus Disease 2019
ECDC – European Centre for Disease Prevention and Control
ESS – European Social Survey
ESS ERIC – European Social Survey European Research Infrastructure Consortium
EU – European Union
EU-SILC – European Union Statistics on Income and Living Conditions
HLS-EU-Q – European Health Literacy Survey Questionnaire
HIV – Human Immunodeficiency Virus
IPW – Inverse Probability Weighting
ISCIII – Carlos III Health Institute (Spain)
JRC – Joint Research Centre (European Commission)
MHI-5 – Mental Health Inventory–5
MSEM – Multigroup Structural Equation Modelling
NCTV – National Coordinator for Security and Counterterrorism (Netherlands)
NIJZ – National Institute of Public Health (Slovenia)
OECD – Organisation for Economic Co-operation and Development
OSF – Open Science Framework
PEPB – Pandemic and Emergency Preparedness Behaviour
RICAPPS – Research Network on Chronicity, Primary Care and Health Promotion
RIVM – National Institute for Public Health and the Environment (Netherlands)
RMSEA – Root Mean Square Error of Approximation
SARS – Severe Acute Respiratory Syndrome
SEM – Structural Equation Modelling
SRMR – Standardized Root Mean Square Residual
TLI – Tucker–Lewis Index
UN – United Nations
VCP – Vaccine Confidence Project
WHO – World Health Organization

Human Ethics and Consent to Participate declaration

Participants were informed about the purpose and procedures of the study and provided electronic informed consent before participation. Participation was voluntary, participants

were reimbursed for their time, and they were free to withdraw from the study at any stage without consequence. The study was reviewed by the Medical Research Ethics Review Committee (MREC) of the National Institute for Public Health and the Environment (RIVM), the Netherlands, which determined that the study was exempt from medical ethical review and issued a declaration to that effect. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data availability
The datasets generated and/or analysed during the current study are publicly available here: https://data.rivm.nl/meta/srv/dut/catalog.search#/metadata/f56b66b4-d7e9-4665-aa31-8a165d2a53fe

Author contributions
All authors contributed to the study design, survey development and data collection. MB and MvD lead on analysis and results. JGS, MB, and MvD led the manuscript writing and revisions. All co-authors contributed to the discussion, manuscript review and revisions.

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The authors declare that they have no competing interests

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Yes

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Supplemental material

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References

Aldrich, D. P., & Meyer, M. A. (2015). Social capital and community resilience. American Behavioral Scientist, 59(2), 254–269.

Allington, D., McAndrew, S., Moxham-Hall, V., & Duffy, B. (2021). Coronavirus conspiracy suspicions, general vaccine attitudes, trust, and coronavirus information source as predictors of vaccine hesitancy. Journal of Psychosomatic Research, 143, 110396.

Allington, D., McAndrew, S., Moxham-Hall, V., & Duffy, B. (2023). Coronavirus conspiracy suspicions, general vaccine attitudes, trust and coronavirus information source as predictors of vaccine hesitancy among UK residents during the COVID-19 pandemic. Psychological Medicine, 53(1), 236–247.

Althubaiti, A. (2016). Information bias in health research: Definition, pitfalls, and adjustment methods. Journal of Multidisciplinary Healthcare, 9, 211–217.

Appleby-Arnold, S., Brockdorff, N., Jakovljev, I., & Zdravković, S. (2021). Disaster preparedness and cultural factors: A comparative study in Romania and Malta. Disasters, 45(3), 664–690.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology, 63*(4), 596–612. https://doi.org/10.1037/0022- 3514.63.4.596

Assari, S., Zare, H., & Sonnega, A. (2024). Education does not equally increase financial well-being for all. Journal of Social Mathematical & Human Engineering Sciences, 3(1), 62.

Bacon, S., Beraneck, M., Boyle, J., Lemos, M., Molloy, G., Raparelli, V., & Lavoie, K. (2025). Cross-national insights into pandemic preparedness from the iCARE study. European Journal of Public Health, 35(Supplement_4), ckaf161–505.

Bargain, O., & Aminjonov, U. (2020). Trust and compliance to public health policies in times of COVID-19. Journal of Public Economics, 192, 104316.

Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PLOS ONE, 13*(12), e0208601.

Betsch, C., Wieler, L. H., & Habersaat, K. (2020). Monitoring behavioural insights related to COVID-19. The Lancet, 395(10232), 1255–1256.

Beca-Martínez MT, Romay-Barja M, Falcón-Romero M, Rodríguez-Blázquez C, Benito-Llanes A, Forjaz MJ. Compliance with the main preventive measures of COVID-19 in Spain: The role of knowledge, attitudes, practices, and risk perception. *Transboundary and Emerging Diseases, 69(4),:*e871-e882. doi: 10.1111/tbed.14364. Epub 2021 Nov 10. PMID: 34730277; PMCID: PMC8661801.

Beca-Martínez MT, Romay-Barja M, Ayala A, Falcon-Romero M, Rodríguez-Blázquez C, Benito A, Forjaz MJ. Trends in COVID-19 Vaccine Acceptance in Spain, September 2020–May 2021. Am J Public Health. 2022 Nov;112(11):1611-1619. doi: 10.2105/AJPH.2022.307039. Epub 2022 Aug 25. PMID: 36007207; PMCID: PMC9558192.

Berwick, D. M., Murphy, J. M., Goldman, P. A., Ware Jr, J. E., Barsky, A. J., & Weinstein, M. C. (1991). Performance of a five-item mental health screening test. *Medical care*, 169-176.

Bish, A., & Michie, S. (2010). Demographic and attitudinal determinants of protective behaviours during a pandemic: A review. *British journal of health psychology*, *15*(4), 797-824.

Boin, A., ’t Hart, P., Stern, E., & Sundelius, B. (2017). The politics of crisis management: Public leadership under pressure (2nd ed.). Cambridge University Press.

Boylan, J. L., & Lawrence, C. (2020). What does it mean to psychologically prepare for a disaster? A systematic review. *International journal of disaster risk reduction*, *45*, 101480.

Brauner, J. M., Mindermann, S., Sharma, M., Johnston, D., Salvatier, J., Gavenciak, T., Bhatt, S. (2021). Inferring the effectiveness of government interventions against COVID-19. *Science, 371*(6531), eabd9338.

Bronfenbrenner, U. (1979). The Ecology of Human Development: Experiments by Nature and Design. Harvard University Press.

Bruder M, Haffke P, Neave N, Nouripanah N, Imhoff R. (2013). Measuring individual differences in generic beliefs in conspiracy theories across cultures: conspiracy mentality monitor. *Front Psychol*. 4:225. doi:10.3389/fpsyg.2013.00225

Bussemakers, C., van Dijk, M., Dima, A. L., & de Bruin, M. (2023). How well do surveys on adherence to pandemic policies assess actual behaviour: Measurement properties of the Dutch COVID-19 adherence to prevention advice survey (CAPAS). *Social Science & Medicine*, 339, 116395.

Byrne-Davis, L. M. T., Turner, R. R., Amatya, S., Ashton, C., Bull, E. R., Chater, A. M., ... & Hart, J. K. (2022). Using behavioral science in public health settings during the COVID-19 pandemic: the experience of public health practitioners and behavioral scientists. *Acta Psychologica, 224*, 103527.

Chen, F. F. (2007). Sensitivity of goodness-of-fit indexes to lack of measurement invariance. Structural Equation Modeling: A Multidisciplinary Journal, 14(3), 464–504.

Chen, Z., & Cong, Z. (2024). The impacts of age and preparation information on perceived and actual preparedness for a pandemic: A latent class analysis. International Journal of Disaster Risk Reduction, 105, 104374.

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. Structural Equation Modeling, 9(2), 233–255.

Curtis, V., & Cairncross, S. (2003). Effect of washing hands with soap on diarrhoea risk in the community: A systematic review. *The Lancet Infectious Diseases*, 3(5), 275–281.

Dalgard, O. S., Dowrick, C., Lehtinen, V., Vazquez-Barquero, J. L., Casey, P., Wilkinson, G., ... & Odin Group. (2006). Negative life events, social support and gender difference in depression: a multinational community survey with data from the ODIN study. *Social psychiatry and psychiatric epidemiology, 41*, 444-451.

de Bruin, W. B., Saw, H.-W., & Goldman, D. P. (2020). Political polarization in US residents' COVID-19 risk perceptions, policy preferences, and protective behaviors. Journal of Risk and Uncertainty, 61(2), 177–194.

de Bruin, M., Suk, J. E., Baggio, M., Blomquist, S. E., Falcon, M., Forjaz, M. J., ... & Kinsman, J. (2022). Behavioural insights and the evolving COVID-19 pandemic. *Eurosurveillance*, *27*(18), 2100615.

De Figueiredo, A., Simas, C., Karafillakis, E., Paterson, P., & Larson, H. J. (2020). Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. *The Lancet*, *396*(10255), 898-908.

De Vries, D.H., Stok, M., Nohlen, H., De Bruin, M., Kinsman, J., Sivelä, J. And Baggio, M. (2024). Behavioral Insights for public health in the EU, Publications Office of the European Union, Luxembourg, doi:10.2760/4538, JRC137884.

DeBastiani, S. D., Strine, T. W., Vagi, S. J., Barnett, D. J., & Kahn, E. B. (2015). Preparedness perceptions, sociodemographic characteristics, and level of household preparedness for public health emergencies. Health Security, 13(5), 317–326.

Devine, D., Gaskell, J., Jennings, W., & Stoker, G. (2021). Trust and the coronavirus pandemic: What are the consequences of and for trust? An early review of the literature. *European Journal of Political Research, 60*(2), 274–285.

Di Giuseppe, G., Abbate, R., Albano, L., Marinelli, P., & Angelillo, I. F. (2008). A survey of knowledge, attitudes and practices towards avian influenza in an adult population of Italy. BMC Infectious Diseases, 8, 36. https://doi.org/10.1186/1471-2334-8-36

Dupuis, M., Baggio, S., & Gmel, G. (2017). Validation of a brief form of the Perceived Neighborhood Social Cohesion monitor. Journal of Health Psychology, 22(2), 218–227.

Eurofound (2021), Living, working and COVID-19 (Update April 2021): Mental health and trust decline across EU as pandemic enters another year, Publications Office of the European Union, Luxembourg.

European Centre for Disease Prevention and Control. (2020). *Guidelines for the implementation of non-pharmaceutical interventions against COVID-19*. ECDC.

European Commission. (2024, September). Disaster risk awareness and preparedness of the EU population (Special Eurobarometer Survey No. 3228). European Union. https://europa.eu/eurobarometer/surveys/detail/3228

European Social Survey European Research Infrastructure Consortium (ESS ERIC). (2024). ESS Round 11 – 2023: Social inequalities in health; Gender in contemporary Europe. Sikt – Norwegian Agency for Shared Services in Education and Research.

European Social Survey ERIC. (2021). *ESS Round 10 Source Monitor*. ESS ERIC Headquarters c/o City, University of London. https://www.europeansocialsurvey.org/methodology/source-monitor

EuroQol Research Foundation. EQ-5D-5L User Guide, 2019. Available from: https://euroqol.org/publications/user-guides

Eurostat. (2026). *European Union Statistics on Income and Living Conditions (EU-SILC) – microdata*. European Commission. https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions

Feng, D., & Ji, L. (2014). Development of a self-administered monitor to assess the psychological competencies for surviving a disaster. Disaster Medicine and Public Health Preparedness, 8(3), 220–228.

De Figueiredo, A., Simas, C., Karafillakis, E., Paterson, P., & Larson, H. J. (2020). Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. The Lancet, 396(10255), 898-908.

Flaxman, S., Mishra, S., Gandy, A., Unwin, H. J. T., Mellan, T. A., Coupland, H., … Bhatt, S. (2020). Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature, 584*, 257–261.

Freeman, D., Waite, F., Rosebrock, L., Petit, A., Causier, C., East, A., ... & Lambe, S. (2022). Coronavirus conspiracy beliefs, mistrust, and compliance with government guidelines in England. *Psychological medicine*, *52*(2), 251-263.

Dolan, P., & Galizzi, M. M. (2015). Like ripples on a pond: Behavioral spillovers and their implications for research and policy. Journal of Economic Psychology, 47, 1-16.

Howard, M. C. (2016). A review of exploratory factor analysis decisions and overview of current practices. International Journal of Human-Computer Interaction, 32(1), 51–62.

Inal, E., Altintas, K. H., & Dogan, N. (2018). The development of a general disaster preparedness belief scale using the health belief model. International Journal of Assessment Tools in Education, 5(1), 146–158.

Kalton, G., & Flores-Cervantes, I. (2003). Weighting methods. Journal of Official Statistics, 19(2), 81–97.

Kelly, B., Squiers, L., Bann, C., Stine, A., Hansen, H., & Lynch, M. (2015). Perceptions and plans for prevention of Ebola: Results from a national survey. BMC Public Health, 15, 1136. https://doi.org/10.1186/s12889-015-2441-7

Kish, L. (1992). Weighting for unequal probabilities. Journal of Official Statistics, 8(2), 183–200.

Kohn, S., Eaton, J. L., Feroz, S., Bainbridge, A. A., Hoolachan, J., & Barnett, D. J. (2012). Personal disaster preparedness: an integrative review of the literature. *Disaster medicine and public health preparedness*, *6*(3), 217-231.

König, H. H., Bernert, S., Angermeyer, M. C., Matschinger, H., Martinez, M., Vilagut, G., et al. (2009). Comparison of population health status in six European countries using the EQ-5D. *Medical Care, 47* (2), 255–261.

Kontodimopoulos, N., Pappa, E., Niakas, D., Yfantopoulos, J., Dimitrakaki, C., & Tountas, Y. (2008). Validity of the EuroQoL (EQ-5D) instrument in a Greek general population. *Value in Health*, *11*(7), 1162-1169.

Lau, J. T. F., Tsui, H. Y., Kim, J. H., et al. (2010). Monitoring of perceptions, anticipated behavioral, and psychological responses related to H5N1 influenza. Infection, 38, 275–283.

Lewandowsky, S., Schmid, P., Habersaat, K.B. et al. Lessons from COVID-19 for behavioral and communication interventions to enhance vaccine uptake. *Communications Psychology, 1*, 35 (2023). https://doi.org/10.1038/s44271-023-00036-7

Mao, Z., Crèvecoeur, J., Pepermans, K., Kind, P., Neyens, T., & Beutels, P. (2024). A comparison of items and constructs of standardized health-related quality of life and mental well-being measures. *Value in Health*, *27*(4), 478-489.

Martinez, A. P., Shevlin, M., Valiente, C., Hyland, P., & Bentall, R. P. (2022). Paranoid beliefs and conspiracy mentality are associated with different forms of mistrust. Frontiers in Psychology, 13, 1023366.

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. Health Education Quarterly, 15(4), 351-377.

Mehra, S., Gorter, A., & de Valk, T. (2024). ‘De pandemie zou aan de deur moeten kloppen, dan pas ga ik zorgen voor dingen’: Paraatheid van burgers voor pandemieën en andere rampen en crises.

Meitinger, K., Davidov, E., Schmidt, P., & Braun, M. (2020). Measurement invariance: Testing for it and explaining why it is absent. Survey Research Methods, 14(4), 345–349.

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel. Implementation Science, 6, 42.

NCTV (National Coordinator for Counterterrorism and Security). (2024). Rapportage Onderzoek naar Weerbaarheidsgedragingen - november 2024. https://www.nctv.nl/documenten/2024/12/04/rapportage-onderzoek-naar-weerbaarheidsgedragingen

OECD. (2017). Trust and public policy: How better governance can help rebuild public trust. OECD Publishing.

Osman, M., & Altıntaş, K. H. (2023). Domains and psychometric properties of scales measuring disaster preparedness among general population: a systematic literature review. *Prehospital and Disaster Medicine*, *38*(5), 636-644.

Paton, D. (2019). Disaster risk reduction: Psychological perspectives on preparedness. Australian Journal of Psychology, 71(4), 327–341.

Peleg, K., Bodas, M., Hertelendy, A. J., & Kirsch, T. D. (2021). The COVID-19 pandemic challenge to the All-Hazards Approach for disaster planning. International Journal of Disaster Risk Reduction, 55, 102103.

Pelikan, J. M., Röthlin, F., Ganahl, K., & Boltzmann, L. (2014, November). Measuring comprehensive health literacy in general populations: validation of instrument, indices and scales of the HLS-EU study. In *Proceedings of the 6th annual health literacy research conference* (pp. 4-6). Bethesda, Rockville, MD: Hyat Regency.

Penta, S., Kendra, J., Marlowe, V., & Gill, K. (2021). A disaster by any other name?: COVID-19 and support for an All-Hazards approach. Risk, hazards & crisis in public policy, 12(3), 240-265.

Petrie, K. J., Faasse, K., & Thomas, M. G. (2016). Public perceptions and knowledge of the Ebola virus, willingness to vaccinate, and likely behavioral responses to an outbreak. Disaster medicine and public health preparedness, 10(4), 674-680.

RIVM (National Institute for Public Health and the Environment). (2026a, March 3). LCI-richtlijnen

RIVM (National Institute for Public Health and the Environment). (2026b, March 3). PIENTER Corona Study. RIVM. https://www.rivm.nl/en/coronavirus-covid-19/pienter-corona-study

RIVM (National Institute for Public Health and the Environment). (2026c, March 3). User Guide Pandemic and Emergency Preparedness and Behaviour Monitor. https://data.rivm.nl/meta/srv/dut/catalog.search#/metadata/f56b66b4-d7e9-4665-aa31-8a165d2a53fe

R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/

Rehberger, M., Lavtar, D., & Klančič, M. (2021). Well-being and depression during the COVID-19 pandemic. *European Journal of Public Health*, *31*(Suppl 3).

Rodríguez-Blázquez, C., Romay-Barja, M., Falcón, M., Ayala, A., & Forjaz, M. J. (2021). The COSMO-Spain survey: three first rounds of the WHO behavioral insights tool. Frontiers in Public Health, 9, 678926.

Ruggeri, K., Stock, F., Haslam, S. A., Capraro, V., Boggio, P., Ellemers, N., ... & Willer, R. (2024). A synthesis of evidence for policy from behavioral science during COVID-19. *Nature, 625* (7993), 134-147.

Salmanton-García, J., Wipfler, P., Leckler, J., Nauclér, P., Mallon, P. W., Bruijning-Verhagen, P. C., ... & Forghieri, F. (2024). Predicting the next pandemic: VACCELERATE ranking of the World Health Organization's Blueprint for Action to Prevent Epidemics. *Travel Medicine and Infectious Disease*, *57*, 102676.

Santos-Ribeiro, C., Rodríguez-Blázquez, C., Ayala, A., Romay-Barja, M., Falcón, M., & Forjaz, M. J. (2025). Evolution of Spanish population well-being during the COVID-19 pandemic: Results from the COSMO-Spain study. Heliyon, 11(3).

Scherpenzeel, A. (2011). Data collection in a probability-based internet panel: The LISS panel. Bulletin of Sociological Methodology, 109(1), 56–61.

Smith, B. W., Dalen, J., Wiggins, K., Tooley, E., Christopher, P., & Bernard, J. (2008). The brief resilience scale: assessing the ability to bounce back. *International Journal of Behavioral Medicine, 15*(3), 194-200

Sørensen, K., Pelikan, J. M., Röthlin, F., Ganahl, K., Slonska, Z., Doyle, G., et al. (2015). Health literacy in Europe. European Journal of Public Health, 25(6), 1053–1058.

Sørensen, K., Van den Broucke, S., Pelikan, J., Fullam, J., Doyle, G., Slonska, Z., Kondilis, B., Stoffels, V., Osborne, R., Brand, H., 2013. Measuring health literacy in populations: illuminating the design and development process of HLS-EU-Q. *BMC Public Health 13,* 948.

Talic, S., Shah, S., Wild, H., Gasevic, D., Maharaj, A., Ademi, Z., … Ilic, D. (2021). Effectiveness of public health measures in reducing the incidence of COVID-19, SARS-CoV-2 transmission, and COVID-19 mortality: Systematic review and meta-analysis. *BMJ, 375*, e068302.

Tourangeau, R., & Yan, T. (2007). Sensitive questions in surveys. Psychological Bulletin, 133(5), 859–883.
van Bavel, J. J., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., et al. (2020). Using social and behavioural science to support COVID-19 pandemic response. Nature Human Behaviour, 4(5), 460–471.
van den Boom, W., van Dijk, M., Snijders, B., Luijben, G., van der Laan, J., Euser, S., et al. (2023). Cohort profile: The Corona Behavioral Unit cohort. PLOS ONE, 18(7), e0289294.
van der Weerd, W., Timmermans, D. R. M., Beaujean, D. J. M. A., Oudhoff, J., & van Steenbergen, J. E. (2011). Monitoring trust, risk perception and behavioural responses during H1N1. Journal of Behavioral Medicine, 34(5), 419–430.
Vrdelja, M., Vrbovšek, S., & Berzelak, N. (2022). Health literacy of adults in Slovenia (HLS-SI19). National Institute of Public Health. https://www.nijz.si/
World Health Organization. (2005). International Health Regulations (2005). World Health Organization. https://www.who.int/publications/i/item/9789241580496
World Health Organisation (2020). Survey tool and guidance: rapid, simple, flexible behavioral insights on COVID-19: July 29, 2020. WHO/EURO:2020-696-40431-54222. https://www.who.int/europe/publications/i/item/WHO-EURO-2020-696-40431-54222

Table 2 Results from measurement invariance analysis as part of structural validity (Models 1-4) and convergent validity (Models 5-6)

		Model fit					Model fit change			
No	**Model**	**Free parameters***	**CFI**	**TLI**	**RMSEA**	**SRMR**	**Comparison model**	**ΔCFI**	**ΔTLI**	**ΔRMSEA**
1	Configural model	1215	0.886	0.872	0.016	0.054				
2	Metric invariance	1089	0.884	0.872	0.016	0.058	1	-0.002	0	0
3	Scalar invariance	978	0.866	0.855	0.017	0.057	2	-0.018	-0.017	0.001
4	Partial scalar invariance (free intercepts for mental health and risk perception, except for 1 item for identification)	1014	0.875	0.864	0.016	0.015	2	-0.009	-0.008	0
5	Metric invariance + covariance invariance	678	0.848	0.843	0.018	0.074	2	-0.036	-0.029	0.002
6	Metric invariance + partial covariance invariance (free covariances for conspiracy and vaccine confidence)	771	0.881	0.876	0.016	0.066	2	-0.003	0.004	0

CFI = Comparative Fit Index, TLI = Tucker-Lewis Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardised Root Mean Square Residual.
* Next to equality constraints typical for configural, metric, and scalar invariance, several model adjustments were made to facilitate adequate estimation of model estimates (e.g., Heywood cases). Details can be found in the scripts on OSF.

Table 4 Percentages of all items/constructs, by country

Item/construct		Ireland				Netherlands				Slovenia				Spain			
		n	%	95% CI	s	n	%	95% CI	s	n	%	95% CI	s	n	%	95% CI	s
Outcomes																	
Reports good general health		1008	71.46	[67.96, 74.71]	↓	1000	82.05	[78.17, 85.37]	↑	1522	79.00	[74.99, 82.53]		1106	72.05	[68.14, 75.66]	↓
Reports good financial health		1008	29.63	[26.2, 33.3]	↓	1000	74.61	[71.17, 77.77]	↑	1522	42.51	[38.48, 46.63]		1106	29.20	[25.38, 33.34]	↓
Reports good mental health		1008	60.00	[56.16, 63.71]	↓	906	79.47	[75.13, 83.22]	↑	1522	71.97	[67.69, 75.89]	↑	1106	51.34	[47.12, 55.55]	↓
Feels that … is prepared for pandemic	…one	1008	32.43	[28.67, 36.43]	↓	1000	34.00	[29.92, 38.33]	↓	1522	53.06	[48.73, 57.35]	↑	1106	34.87	[30.97, 38.98]	↓
	…employer	636	45.90	[41.64, 50.23]		487	53.30	[47.7, 58.82]		766	48.58	[43.33, 53.85]		533	49.16	[44.04, 54.3]	
	…government	1008	37.40	[33.77, 41.18]	↑	996	33.88	[29.78, 38.24]		1522	25.88	[22.4, 29.69]	↓	1106	34.36	[30.41, 38.55]	
Behaviours																	
Washes hands most of the time after...	…coughing, sneezing, blowing nose	994	69.14	[65.52, 72.55]	↑	945	47.09	[42.95, 51.26]	↓	1491	70.47	[66.45, 74.21]	↑	1092	56.72	[52.53, 60.81]	↓
	…preparing or eating food	1000	83.89	[80.96, 86.45]	↓	971	85.57	[82.56, 88.13]		1505	91.91	[88.44, 94.41]	↑	1096	84.93	[82.13, 87.35]	↓
	…using the toilet	995	91.45	[89.15, 93.3]		984	92.41	[90.32, 94.08]		1508	96.39	[93.94, 97.87]	↑	1094	82.65	[79.42, 85.46]	↓
	…cleaning the house	983	82.84	[79.72, 85.56]	↓	935	76.34	[72.84, 79.52]	↓	1499	94.41	[92.45, 95.89]	↑	1087	75.93	[72.16, 79.33]	↓
	…entering home	994	63.98	[60.26, 67.55]	↓	975	48.86	[44.7, 53.03]	↓	1508	82.85	[79.63, 85.66]	↑	1098	67.85	[64.06, 71.42]	
Coughs or sneezes in elbow most of the time		960	56.66	[52.76, 60.49]	↑	904	58.59	[54.09, 62.95]	↑	1322	55.09	[50.44, 59.66]		1004	39.26	[34.9, 43.79]	↓
Stayed at home while feeling sick		334	25.90	[20.56, 32.06]	↓	221	16.84	[12.23, 22.75]	↓		*1		↑	364	30.72	[24.55, 37.67]	
Had physical contact with someone vulnerable to infections while having symptoms		572	19.21	[15.5, 23.55]	↑	458	13.13	[9.95, 17.14]			*1		↓	639	20.25	[16.34, 24.82]	↑
Had physical contact with others yesterday		1008	70.10	[66.51, 73.46]	↑	993	63.13	[58.99, 67.08]		1522	67.35	[62.62, 71.75]		1106	64.36	[59.96, 68.53]	
	Has a 3-day stock of food, drinks, and meds and home	1008	66.66	[63.08, 70.05]	↓	993	63.36	[59.41, 67.14]	↓	1473	83.92	[80.5, 86.83]	↑	1106	70.37	[66.29, 74.15]	

Household preparedness	Has a first aid kit at home	1008	78.14	[75.08, 80.92]	↓	993	73.81	[69.97, 77.33]	↓	1475	93.08	[90.74, 94.86]	↑	1106	79.85	[76.49, 82.85]	↓
	Has a 3-day stock of water at home	1008	57.15	[53.39, 60.82]	↑	993	29.16	[25.25, 33.41]	↓	1476	50.08	[45.73, 54.43]		1106	57.43	[53.24, 61.52]	↑
	Has face masks, sanitizer, and soap at home	1008	75.78	[72.62, 78.69]		993	64.75	[60.81, 68.51]	↓	1462	77.60	[73.83, 80.97]	↑	1106	76.06	[72.63, 79.18]	
	Receives government alerts	798	55.02	[50.64, 59.33]	↓	696	71.94	[66.75, 76.61]	↑	1366	46.95	[42.44, 51.5]	↓	907	76.58	[72.52, 80.2]	↑
	'Good' household preparedness (scale)	1008	48.35	[44.53, 52.19]		1000	35.94	[31.99, 40.10]	↓	1522	48.29	[43.97, 52.64]		1106	54.17	[49.93, 58.35]	↑
Capability																	
Reported health literacy	Sufficient (scale)	891	43.07	[39.04, 47.19]		770	60.14	[55.73, 64.4]	↑	1322	45.91	[41.39, 50.49]		927	36.79	[32.54, 41.25]	↓
	Problematic (scale)	891	43.58	[39.65, 47.58]		770	36.32	[32.16, 40.7]	↓	1322	49.48	[44.93, 54.03]	↑	927	49.90	[45.34, 54.47]	↑
	Inadequate (scale)	891	13.35	[10.88, 16.29]	↑	770	3.53	[2.34, 5.3]	↓	1322	4.62	[3.37, 6.29]	↓	927	13.31	[10.75, 16.36]	↑
Reports high mental resilience (scale)		1008	27.97	[24.57, 31.65]	↓	988	34.06	[30.46, 37.86]		1522	42.06	[38, 46.24]	↑	1106	31.97	[28.09, 36.12]	
Opportunity																	
Needed medical examination/treatment in past year		1008	60.54	[56.78, 64.18]		988	45.68	[41.67, 49.75]	↓	1522	67.17	[63.1, 70.99]	↑	1106	62.70	[58.55, 66.67]	
Has an unmet care need		1008	12.30	[10.25, 14.68]	↑	988	4.14	[2.84, 5.99]	↓	1522	10.29	[8.17, 12.88]	↑	1106	6.96	[5.51, 8.77]	
Reported social support	Strong (scale)	1008	13.88	[10.91, 17.5]	↓	987	37.96	[34.01, 42.07]	↑	1522	18.04	[15.25, 21.21]	↓	1106	20.66	[17.4, 24.35]	
	Moderate (scale)	1008	45.20	[41.38, 49.07]	↓	987	44.63	[40.52, 48.81]	↓	1522	55.09	[50.8, 59.3]	↑	1106	50.46	[46.22, 54.69]	
	Poor (scale)	1008	40.92	[37.28, 44.66]	↑	987	17.42	[14.87, 20.3]	↓	1522	26.87	[23.25, 30.83]		1106	28.88	[25.34, 32.71]	
Reports strong social cohesion (scale)		1008	46.39	[42.55, 50.28]		979	61.85	[57.87, 65.68]	↑	1522	38.86	[34.83, 43.05]	↓	1106	47.24	[42.99, 51.54]	
Motivation																	
Has high trust in…	…the government	1008	37.87	[33.99, 41.9]	↑	985	33.99	[29.73, 38.52]	↑	1522	21.77	[18.61, 25.3]	↓	1106	28.83	[24.8, 33.24]	
	…politicians	1008	27.11	[23.34, 31.25]	↑	985	19.75	[15.95, 24.19]	↑	1522	6.95	[5.17, 9.28]	↓	1106	13.16	[10.17, 16.86]	
	…political parties	1008	24.65	[20.95, 28.75]	↑	985	17.99	[14.26, 22.45]	↑	1522	5.21	[3.69, 7.31]	↓	1106	11.74	[9.25, 14.79]	
	politics (scale)	1008	26.74	[23.00, 30.84]	↑	985	19.93	[16.13, 24.38]	↑	1522	8.18	[6.12, 10.86]	↓	1106	14.48	[11.28, 18.41]	

	…the police	1008	47.47	[43.62, 51.35]		985	62.49	[58.71, 66.12]	↑	1522	45.60	[41.29, 49.96]	↓	1106	50.00	[45.76, 54.25]	
	…science	1008	62.46	[58.77, 66.01]		985	68.89	[65.36, 72.22]	↑	1522	57.18	[52.82, 61.44]	↓	1106	66.42	[62.5, 70.13]	
	…healthcare	1008	44.25	[40.37, 48.19]	↓	985	69.37	[65.79, 72.73]	↑	1522	35.34	[31.22, 39.68]	↓	1106	58.68	[54.61, 62.64]	↑
	…doctors	1008	61.31	[57.6, 64.89]		985	77.34	[74.05, 80.33]	↑	1522	50.30	[45.97, 54.61]	↓	1106	66.80	[62.99, 70.4]	↑
	national institutions (scale)	1008	52.45	[48.63, 56.24]	↓	985	72.71	[69.33, 75.84]	↑	1522	46.27	[41.97, 50.63]	↓	1106	63.35	[59.44, 67.09]	↑
	…European institutions	1008	34.73	[30.85, 38.82]	↑	985	29.73	[25.56, 34.27]	↑	1522	19.05	[15.82, 22.77]	↓	1106	24.52	[20.78, 28.7]	
	…United Nations	1008	37.72	[33.84, 41.76]	↑	985	39.34	[35.13, 43.71]	↑	1522	18.42	[15.25, 22.08]	↓	1106	27.09	[23.31, 31.23]	
	…World Health Organization	1008	46.60	[42.72, 50.52]	↑	985	49.05	[44.93, 53.17]	↑	1522	24.00	[20.72, 27.61]	↓	1106	36.97	[32.8, 41.34]	
	international institutions (scale)	1008	38.64	[34.76, 42.68]	↑	985	37.35	[33.14, 41.76]	↑	1522	17.16	[14.28, 20.47]	↓	1106	27.35	[23.48, 31.60]	
	…the law	1008	44.41	[40.52, 48.37]	↑	985	57.51	[53.56, 61.37]	↑	1522	24.92	[21.5, 28.69]	↓	1106	26.94	[23.04, 31.22]	↓
	…media	1008	23.11	[19.59, 27.04]	↑	985	20.26	[17.07, 23.88]		1522	11.58	[8.78, 15.14]	↓	1106	21.91	[18.39, 25.87]	↑
	…ministry of health	1008	34.02	[30.17, 38.08]		985	41.39	[37.18, 45.72]	↑	1522	22.15	[18.44, 26.36]	↓	1106	37.99	[33.74, 42.43]	↑
	…national public health agency	1008	37.48	[33.64, 41.48]		985	51.17	[47.05, 55.28]	↑	1522	27.15	[23.18, 31.51]	↓	1106	49.83	[45.58, 54.07]	↑
Feels confident about vaccines (scale)		1008	67.59	[64.02, 70.96]		986	81.65	[78.59, 84.35]	↑	1522	51.08	[46.74, 55.41]	↓	1106	72.39	[68.78, 75.73]	↑
Endorses conspiracy beliefs (scale)		1008	52.64	[48.79, 56.46]		981	28.82	[25.01, 32.95]	↓	1522	69.45	[65.55, 73.09]	↑	1106	62.45	[58.33, 66.39]	↑
Thinks that … are likely to occur within 5 years within country	…man-made disasters	945	19.74	[16.85, 22.99]		899	25.46	[22, 29.27]	↑	1469	12.89	[10.03, 16.41]	↓	1005	27.49	[23.41, 31.98]	↑
	…infectious outbreak	902	31.82	[28.23, 35.64]	↑	900	25.30	[22.04, 28.86]	↑	1460	11.90	[9.38, 15]	↓	962	28.82	[25.08, 32.87]	↑
	…natural disaster	953	36.61	[32.81, 40.58]	↓	923	41.73	[37.63, 45.95]		1485	41.29	[37.08, 45.63]		1028	41.20	[36.92, 45.62]	
	…terrorist attack	925	28.81	[25.14, 32.77]	↑	902	28.25	[24.77, 32.02]	↑	1469	10.94	[8.59, 13.83]	↓	969	29.33	[25.43, 33.55]	↑
	…armed conflict	946	27.42	[23.79, 31.38]	↑	900	24.89	[21.56, 28.54]	↑	1446	10.60	[8.24, 13.54]	↓	978	27.13	[23.31, 31.33]	↑

	all disasters (scale)	924	24.60	[21, 28.59]	↑	895	25.70	[22.27, 29.46]	↑	1457	8.50	[6.54, 10.98]	↓	963	26.26	[22.39, 30.55]	↑
Would be personally affected by…	…man-made disasters	894	72.87	[69.27, 76.2]	↓	833	74.08	[70.06, 77.72]		1446	82.87	[79.31, 85.93]	↑	1022	74.84	[70.87, 78.42]	
	…infectious outbreak	909	81.84	[78.6, 84.69]		864	79.61	[75.77, 82.97]		1460	78.86	[74.99, 82.27]		998	82.67	[79.19, 85.67]	
	…natural disaster	913	75.33	[71.85, 78.5]	↓	860	83.75	[80.64, 86.45]		1470	89.59	[86.96, 91.74]	↑	1017	83.48	[80.38, 86.19]	
	…terrorist attack	891	73.21	[69.53, 76.6]	↓	836	85.54	[82.65, 88.01]		1435	91.73	[89.4, 93.58]	↑	988	82.69	[79.14, 85.75]	
	…armed conflict	905	75.87	[72.34, 79.08]	↓	845	87.50	[83.02, 90.93]		1444	93.78	[90.18, 96.12]	↑	1014	82.81	[79.13, 85.96]	↓
	all disasters (scale)	890	68.32	[64.53, 71.89]	↓	830	79.15	[75.58, 82.32]		1448	84.38	[80.51, 87.61]	↑	992	71.99	[67.82, 75.81]	↓

See Supplementary Material 1 for all questions and cut-offs applied. 1 = question as it was asked in Slovenia as follows: ”In the event that you had symptoms of a severe cold of flu, would you visit someone who could become seriously ill if they contracted a respiritory infection (for example a person over 70 years old or someone with a severely weakened immune system)?” cross *all* respondents (n = 1522), 61.41% [57.21, 65.45] reported that they would stay at home if they were to feel sick, and 2.71% [1.29, 5.60] would visit someone vulnerable to infectious diseases if they were to experience symptoms of illness.

n = weighted sample size, s = significant with respect to the pooled average at $p < 0.05$, ↑ = higher than pooled average, ↓ lower than pooled average.

Supplementary Files

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