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Predicting attitudinal and behavioral responses to COVID-19 pandemic using machine learning

Tomislav Pavlović ^{ID a,*}, Flavio Azevedo ^{ID b}, Koustav De ^{ID c}, Julián C. Riaño-Moreno ^{ID d}, Marina Maglić ^{ID a},
 Theofilos Gkinopoulos ^{ID e}, Patricio Andreas Donnelly-Kehoe ^{ID f}, César Payán-Gómez ^{ID g}, Guanxiong Huang ^{ID h},
 Jaroslaw Kantorowicz ^{ID i}, Michèle D. Birtel ^{ID j}, Philipp Schönegger ^{ID k}, Valerio Capraro ^{ID l}, Hernando Santamaría-García ^{ID m},
 Meltem Yucel ^{ID n}, Agustín Ibanez ^{ID o,p,q,r}, Steve Rathje ^{ID s}, Erik Wetter ^{ID t}, Dragan Stanojević ^{ID u}, Jan-Willem van Prooijen ^{ID v},
 Eugenia Hesse ^{ID w}, Christian T. Elbaek ^{ID x}, Renata Franc ^{ID a}, Zoran Pavlović ^{ID y}, Panagiotis Mitkidis ^{ID x}, Aleksandra Cichocka ^{ID z},
 Michele Gelfand ^{aa}, Mark Alfano ^{ID bb}, Robert M. Ross ^{ID bb}, Hallgeir Sjøstad ^{ID cc}, John B. Nezlek ^{ID dd}, Aleksandra Cislak ^{ID ee},
 Patricia Lockwood ^{ID ff,gg}, Koen Abts ^{ID hh}, Elena Agadullina ^{ID ii}, David M. Amodio ^{ID jj}, Matthew A. J. Apps ^{ID ff}, John Jamir
 Benzon Aruta ^{ID kk}, Sahba Besharati ^{ID ll}, Alexander Bor ^{ID mm}, Becky Choma ^{ID nn}, William Cunningham ^{oo}, Waqas Ejaz ^{ID pp},
 Harry Farmer ^{ID qq}, Andrej Findor ^{ID rr}, Biljana Gjoneska ^{ID ss}, Estrella Gualda ^{ID tt}, Toan L. D. Huynh ^{ID uu}, Mostak Ahamed Imran ^{ID vv},
 Jacob Israelashvili ^{ID ww}, Elena Kantorowicz-Reznichenko ^{ID xx}, André Krouwel ^{ID yy}, Yordan Kutiytski ^{ID zz}, Michael Laakasuo ^{ID aaa},
 Claus Lamm ^{ID bbb}, Jonathan Levy ^{ID ccc,ddd}, Caroline Leygue ^{ID eee}, Ming-Jen Lin ^{ID fff}, Mohammad Sabbir Mansoor ^{ID ggg},
 Antoine Marie ^{ID mm}, Lewend Mayiwar ^{ID hhh}, Honorata Mazepus ^{ID iii}, Cillian McHugh ^{ID jjj}, Andreas Olsson ^{ID kkk},
 Tobias Otterbring ^{ID ll}, Dominic Packer ^{ID mmm}, Jussi Palomäki ^{ID nnn}, Anat Perry ^{ID ww}, Michael Bang Petersen ^{ID mm},
 Arathy Puthillam ^{ID ooo}, Tobias Rothmund ^{ID ppp}, Petra C. Schmid ^{ID qqq}, David Stadelmann ^{ID rrr}, Augustin Stoica ^{ID sss},
 Drozdstoy Stoyanov ^{ID ttt}, Kristina Stoyanova ^{ID uuu}, Shruti Tewari ^{ID vvv}, Bojan Todosijević ^{ID www}, Benno Torgler ^{ID xxx},
 Manos Tsakiris ^{ID yyy,zzz}, Hans H. Tung ^{ID aaaa}, Radu Gabriel Umbreş ^{ID bbbb}, Edmunds Vanags ^{ID cccc}, Madalina Vlasceanu ^{ID dddd},
 Andrew J. Vonasch ^{ID eeee}, Yucheng Zhang ^{ID ffff}, Mohcine Abad ^{ID gggg}, Eli Adler ^{ID ww,ccc}, Hamza Alaoui Mdarhri ^{ID gggg},
 Benedict Antazo ^{ID hhhh}, F. Ceren Ay ^{ID iii}, Mouhamadou El Hady Ba ^{ID jjj}, Sergio Barbosa ^{ID kkkk}, Brock Bastian ^{ID ll}, Anton Berg ^{ID nnn},
 Michał Białek ^{ID mmmm}, Ennio Bilancini ^{ID nnnn}, Natalia Bogatyreva ^{ID oooo}, Leonardo Boncinelli ^{ID pppp}, Jonathan E. Booth ^{ID qqqq},
 Sylvie Borau ^{ID rrrr}, Ondrej Buchel ^{ID ssss,ttt}, Chrissie Ferreira de Carvalho ^{ID uuuu}, Tatiana Celadin ^{ID vvvv}, Chiara Cerami ^{ID wwww}, Hom
 Nath Chalise ^{ID xxxx}, Xiaojun Cheng ^{ID yyyy}, Luca Cian ^{ID zzzz}, Kate Cockcroft ^{ID ll}, Jane Conway ^{ID aaaaa}, Mateo A. Córdoba-Delgado ^{ID bbbb},
 Chiara Crespi ^{ID ccccc}, Marie Crouzevialle ^{ID qqq}, Jo Cutler ^{ID dddd,eeee}, Marzena Cypryńska ^{ID dd}, Justyna Dabrowska ^{ID ffff}, Victoria
 H. Davis ^{ID gggg}, John Paul Minda ^{ID hhhh}, Pamala N. Dayley ^{ID iiiii}, Sylvain Delouvé ^{ID jjjj}, Ognjan Denkovski ^{ID kkkk},
 Guillaume Dezechache ^{ID llll}, Nathan A. Dhaliwal ^{ID mmmmm}, Alelie Diato ^{ID nnnnn}, Roberto Di Paolo ^{ID nnnn}, Uwe Dulleck ^{ID ooooo},
 Jānis Ekmanis ^{ID ppppp}, Tom W. Etienne ^{ID qqqqq}, Hapsa Hossain Farhana ^{ID rrrr}, Fahima Farkhari ^{ID ssss,tttt}, Kristijan Fidanovski ^{ID uuuuu},
 Terry Flew ^{ID vvvvv}, Shona Fraser ^{ID wwwww}, Raymond Boadi Frempong ^{ID rrr}, Jonathan Fugelsang ^{ID xxxxx}, Jessica Gale ^{ID eeee},
 E. Begoña García-Navarro ^{ID yyyyy}, Prasad Garladinne ^{ID vv}, Kurt Gray ^{ID zzzzz}, Siobhán M. Griffin ^{ID jjj}, Bjarki Gronfeldt ^{ID z},
 June Gruber ^{ID aaaaaa}, Eran Halperin ^{ID ww}, Volo Herzon ^{ID nnn}, Matej Hruška ^{ID rr}, Matthias F. C. Hudecek ^{ID bbbbbb}, Ozan Isler ^{ID ooooo},
 Simon Jangard ^{ID kkk}, Frederik Jørgensen ^{ID mm}, Oleksandra Keudel ^{ID ccccc}, Lina Koppel ^{ID ddddd}, Mika Koverola ^{ID nnn},
 Anton Kunnari ^{ID eeeee}, Josh Leota ^{ID fffff}, Eva Lerner ^{ID ggggg,hhhhh}, Chunyun Li ^{ID qqqq}, Chiara Longoni ^{ID iiiiii},
 Darragh McCashin ^{ID jjjjj}, Igor Mikloušić ^{ID a}, Juliana Molina-Paredes ^{ID kkkkk}, César Monroy-Fonseca ^{ID lllll},
 Elena Morales-Marente ^{ID mmmmm}, David Moreau ^{ID nnnnn}, Rafał Muda ^{ID ooooo}, Annalisa Myer ^{ID ppppp}, Kyle Nash ^{ID qqqqq}, Jonas
 P. Nitschke ^{ID bbb}, Matthew S. Nurse ^{ID rrrrr}, Victoria Oldemburgo de Mello ^{ID oo}, Maria Soledad Palacios-Galvez ^{ID mmmmm},
 Jussi Palomäki ^{ID nnn}, Yafeng Pan ^{ID sssss}, Zsófia Papp ^{ID ttttt}, Philip Pärnamets ^{ID kkk}, Mariola Paruzel-Czachura ^{ID uuuuu,vvvvv},
 Silva Perander ^{ID wwwww}, Michael Pitman ^{ID ll}, Ali Raza ^{ID xxxxx}, Gabriel Gaudencio Rêgo ^{ID yyyyy}, Claire Robertson ^{ID zzzzz},
 Iván Rodríguez-Pascual ^{ID mmmmm}, Teemu Saikkonen ^{ID aaaaaa}, Octavio Salvador-Ginez ^{ID bbbbbb}, Waldir M. Sampaio ^{ID yyyyy}, Gaia
 Chiara Santi ^{ID ccccc}, David Schultner ^{ID ddddd}, Enid Schutte ^{ID ll}, Andy Scott ^{ID ppppp}, Ahmed Skali ^{ID eeeee}, Anna Stefaniak ^{ID fffff},
 Anni Sternisko ^{ID zzzzz}, Brent Strickland ^{ID ggggg,hhhhh}, Jeffrey P. Thomas ^{ID qqqq}, Gustav Tinghög ^{ID ccccc}, Iris J. Traast ^{ID iiiii},
 Raffaele Tucciarelli ^{ID jjjjj}, Michael Tyralla ^{ID kkkkk}, Nick D. Ungson ^{ID lllll}, Mete Sefa Uysal ^{ID mmmmm}, Dirk Van Rooy ^{ID nnnnn},
 Daniel Västfjäll ^{ID ooooo}, Joana B. Vieira ^{ID kkk,ppppp}, Christian von Sikorski ^{ID qqqqqq}, Alexander C. Walker ^{ID wwwww},
 Jennifer Watermeyer ^{ID rrrrr}, Robin Willardt ^{ID qqq}, Michael J. A. Wohl ^{ID fffff}, Adrian Dominik Wójcik ^{ID sssss}, Kaidi Wu ^{ID ttttt},

Competing Interest: The authors declare no competing interest.

Received: November 27, 2021. **Accepted:** June 21, 2022

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Yuki Yamada ^{ID} [uuuuuuu](#), Onurcan Yilmaz ^{ID} [vvvvvvv](#), Kumar Yogeewaran ^{ID} [eeee](#), Carolin-Theresa Ziemer ^{ID} [tttt](#),
 Rolf A. Zwaan ^{ID} [wwwwwww](#), Paulo Sergio Boggio ^{ID} [yyyyyy](#), Ashley Whillans ^{xxxxxxx}, Paul A. M. Van Lange ^{ID} [v](#), Rajib Prasad ^{ID} [yyyyyyy](#),
 Michal Onderco ^{ID} [zzzzzz](#), Cathal O'Madagain ^{ID} [gggg](#), Tarik Nesh-Nash ^{ID} [aaaaaaa](#), Oscar Moreda Laguna ^{zz}, Emily Kubin ^{ID} [qqqqqqq](#),
 Mert Gümren ^{ID} [bbbbbbb](#), Ali Fenwick ^{ID} [ccccccc](#), Arhan S. Ertan ^{ID} [ddddddd](#), Michael J. Bernstein ^{ID} [eeeeeee](#), Hanane Amara ^{ID} [bbbbbbb](#) and
 Jay Joseph Van Bavel ^{ID} [zzzzzz](#)

^aInstitute of Social Sciences Ivo Pilar, Zagreb, Croatia

^bDepartment of Psychology, Cambridge University, Cambridge, UK

^cDepartment of Finance and Quantitative Methods, Gatton College of Business and Economics, University of Kentucky, Lexington, KY, USA

^dFaculty of Medicine, Cooperative University of Colombia, Villavicencio, Meta, Colombia and Department of bioethics, El Bosque University, Bogotá D.C. Colombia

^eDepartment of Philosophy and Social Studies, University of Crete, Rethymnon, Crete, Greece

^fDepartment of Research and Development, Kozaca SA, Rosario, Santa Fe, Argentina

^gDirección Académica Sede la Paz, Universidad Nacional de Colombia - Sede de La Paz, Cesar, Colombia

^hDepartment of Media and Communication, City University of Hong Kong, Kowloon Tong, Hong Kong

ⁱDepartment of Economics, Institute of Security and Global Affairs, Leiden University, The Hague, Netherlands

^jSchool of Human Sciences, University of Greenwich, London, UK

^kDepartment of Philosophy, School of Economics and Finance, University of St Andrews, St Andrews, UK

^lDepartment of Economics, Middlesex University London, London, UK

^mDepartment of Psychiatry, Pontifical Xavierian University, Bogotá, Colombia

ⁿDepartment of Psychology and Neuroscience, Duke University, Durham, NC, USA

^oLatin American Brain Health Institute (BrainLat), Universidad Adolfo Ibañez, Santiago, Peñalolén, Chile

^pCognitive Neuroscience Center (CNC), University of San Andrés and CONICET, Buenos Aires, Argentina

^qGlobal Brain Health Institute, University of California - San Francisco, San Francisco, CA, USA

^rGlobal Brain Health Institute, Trinity College, Dublin, Ireland

^sDepartment of Psychology, University of Cambridge, Cambridge, UK

^tDepartment of Business Administration, Stockholm School of Economics, Stockholm, Sweden

^uDepartment of Sociology, Faculty of Philosophy, University of Belgrade, Belgrade, Serbia

^vDepartment of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, Amsterdam, Netherlands

^wDepartamento de Matemática y Ciencias, Universidad de San Andrés, Victoria, Buenos Aires, Argentina

^xDepartment of Management, Aarhus University, Aarhus, Denmark

^yDepartment of Psychology, Faculty of Philosophy, University of Belgrade, Belgrade, Serbia

^zSchool of Psychology, University of Kent, Canterbury, UK

^{aa}Stanford Graduate School of Business, Stanford University, Stanford, California, USA

^{bb}Department of Philosophy, Macquarie University, Macquarie Park, New South Wales, Australia

^{cc}Department of Strategy and Management, Norwegian School of Economics, Bergen, Norway

^{dd}Institute of Psychology, Center for Climate Action and Social Transformations, SWPS, University of Social Sciences and Humanities, Warsaw, Poland

^{ee}Institute of Psychology, SWPS University of Social Sciences and Humanities, Warsaw, Poland

^{ff}Centre for Human Brain Health, School of Psychology, University of Birmingham, Birmingham, UK

^{gg}Department of Experimental Psychology, University of Oxford, Oxford, UK

^{hh}Centre for Sociological Research, Katholieke Universiteit Leuven, Leuven, Belgium

ⁱⁱFaculty of Psychology, Higher School of Economics University, Moscow, Russia

^{jj}Department of Psychology, University of Amsterdam, Amsterdam, Netherlands

^{kk}Department of Psychology, Sunway University, Petaling Jaya, Selangor, Malaysia

^{ll}Department of Psychology, University of the Witwatersrand, Johannesburg, Republic of South Africa

^{mm}Department of Political Science, Aarhus University, Aarhus, Denmark

ⁿⁿDepartment of Psychology, Toronto Metropolitan University, Toronto, Ontario, Canada

^{oo}Department of Psychology, University of Toronto, Toronto, Ontario, Canada

^{pp}Department of Mass Communication, National University of Science and Technology (NUST), Islamabad, Islamabad Capital Territory, Pakistan

^{qq}Department of Psychology, University of Greenwich, London, UK

^{rr}Institute of European Studies and International Relations, Faculty of Social and Economic Sciences, Comenius University, Bratislava, Slovakia

^{ss}Macedonian Academy of Sciences and Arts, Skopje, Republic of North Macedonia

^{tt}Department of Sociology, Social Work and Public Health, University of Huelva, Huelva, Spain

^{uu}Department of Decision Analytics and Risk, University of Southampton, Southampton, UK

^{vv}Department of Educational and Counselling Psychology, BRAC Institute of Educational and Development, BRAC University, Dhaka, Bangladesh

^{ww}Department of Psychology, Hebrew University of Jerusalem, Jerusalem, Israel

^{xx}Rotterdam Institute of Law and Economics (RILE), Erasmus University Rotterdam, Rotterdam, Netherlands

^{yy}Department of Communication Science, Vrije Universiteit Amsterdam, Amsterdam, Netherlands

^{zz}Kieskompas (Election Compass), Amsterdam, Netherlands

^{aaa}Department of Digital Humanities, University of Helsinki, Helsinki, Finland

^{bbb}Department of Cognition, Emotion, and Methods in Psychology, University of Vienna, Wien, Austria

^{ccc}Department of Neuroscience and Biomedical Engineering, Aalto University, Espoo, Finland

^{ddd}Baruch Ivcher School of Psychology, Reichman University, Herzliya, Israel

^{eee}School of Psychology, Universidad Nacional Autónoma de México, Mexico City, Mexico

^{fff}Department of Economics, National Taiwan University, Taipei, Taiwan

^{ggg}HEMS School, Kathmandu, Nepal

^{hhh}Department of Leadership and Organizational Behaviour, BI Norwegian Business School, Oslo, Norway

ⁱⁱⁱInstitute of Security and Global Affairs, Leiden University, The Hague, Netherlands

^{jjj}Department of Psychology, University of Limerick, Limerick, Ireland

^{kkk}Department of Clinical Neuroscience, Karolinska Institutet, Stockholm, Sweden

^{lll}Department of Management, University of Agder, Kristiansand, Norway

^{mmm}Department of Psychology, Lehigh University, Bethlehem, PA, USA

ⁿⁿⁿDepartment of Digital Humanities, University of Helsinki, Helsinki, Finland

^{ooo}Department of Psychology, Monk Prayogshala, Powai, Mumbai, Maharashtra, India

^{ppp}Department of Social and Behavioral Science, Friedrich Schiller University Jena, Jena, Germany

^{qqq}Department of Management, Technology, and Economics, Swiss Federal Institute of Technology in Zürich, Zürich, Switzerland

- rrr Chair of Development Economics, University of Bayreuth, Bayreuth, Germany
- sss Department of Sociology, National School for Political and Administrative Studies (SNSPA), Bucharest, Romania
- ttt Department of Psychiatry and Medical Psychology, Medical University, Plovdiv, Bulgaria
- uuu Division of Translational Neuroscience, Medical University, Plovdiv, Bulgaria
- vvv Humanities and Social Sciences, Indian Institute of Management, Indore, Madhya Pradesh, India
- www Institute of Social Sciences, Belgrade, Serbia
- xxx School of Economics and Finance and Centre for Behavioural Economics, Society and Technology (BEST), Queensland University of Technology, Brisbane City, Queensland, Australia
- yyy Department of Psychology, Royal Holloway, University of London, Egham, UK
- zzz Centre for the Politics of Feelings, School of Advanced Study, University of London, London, UK
- aaaa Department of Political Science, National Taiwan University, Taipei, Taiwan
- bbbb Faculty of Political Science, National University of Political Studies and Public Administration, Bucharest, Romania
- cccc Psychology Department, University of Latvia, Riga, Latvia
- dddd Department of Psychology, New York University, New York, NY, USA
- eeee School of Psychology, Speech, and Hearing, University of Canterbury, Christchurch, New Zealand
- ffff School of Economics and Management, Hebei University of Technology, Tianjin, China
- gggg School of Collective Intelligence, Mohammed VI Polytechnic University, Ben Guerir, Morocco
- hhhh Department of Psychology, Jose Rizal University, Mandaluyong, Metro Manila, Philippines
- iiii Department of Economics, Telenor Research, Fornebu, Norway
- jjjj Cheikh Anta Diop University, Dakar, Senegal
- kkkk School of Medicine and Health Sciences, Universidad del Rosario, Bogotá, Colombia
- llll Melbourne School of Psychological Sciences, University of Melbourne, Melbourne, Victoria, Australia
- mmmm Faculty of Historical and Pedagogical Sciences, University of Wrocław, Wrocław, Poland
- nnnn IMT School for Advanced Studies, Lucca, Italy
- oooo Laboratory for Psychology of Social Inequality, Higher School of Economics University, Moscow, Russia
- pppp Department of Economics and Management, University of Florence, Florence, Italy
- qqqq Department of Management, London School of Economics and Political Science, London, UK
- rrrr Department of Marketing, TBS Education, Toulouse, France
- ssss The Institute for Sociology, Slovak Academy of Sciences, Bratislava, Slovakia
- tttt Social Policy Institute, Ministry of Labor, Family and Social Affairs of the Slovak Republic, Bratislava, Slovakia
- uuuu Department of Psychology, Federal University of Santa Catarina, Florianopolis, Brazil
- vvvv Department of Economics, University of Bologna, Bologna, Italy
- wwww IUSS Cognitive Neuroscience Center, University School for Advanced Studies, Pavia, Italy
- xxxx Central Department of Population Studies, Tribhuvan University, Kathmandu, Nepal
- yyyy School of Psychology, Shenzhen University, Shenzhen, China
- zzzz Department of Marketing, Darden School of Business, University of Virginia, Charlottesville, VA, USA
- aaaaa MRC Social, Genetic and Developmental Psychiatry Centre, Institute for Advanced Study in Toulouse, Université Toulouse 1 Capitole, Toulouse Cedex 6, France
- bbbbb Faculty of Medicine, Pontifical Xavierian University, Bogotá, Colombia
- ccccc U.O. Rho, Fondazione Luigi Clerici, Rho, Italy
- ddddd School of Psychology, University of Birmingham, Birmingham, UK
- eeeee School of Psychology, University of Oxford, Oxford, UK
- fffff Department of Trade and Market Institutions, Cracow University of Economics, Kraków, Poland
- ggggg Institute of Health Policy, Management and Evaluation, Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada
- hhhhh Department of Psychology, Western University, London, Ontario, Canada
- iiiiii Department of Psychology, University of California - Los Angeles, Los Angeles, CA, USA
- jjjjj Department of Psychology, Université Rennes 2, Rennes, France
- kkkkk Department of Communication Science, University of Amsterdam, Amsterdam, Netherlands
- lllll Université Clermont Auvergne LAPSCO, CNRS, Clermont-Ferrand, France
- mmmmm UBC Sauder School of Business, University of British Columbia, Vancouver, British Columbia, Canada
- nnnnn Teacher Education Department, Cavite State University, General Trias, Cavite, Philippines
- ooooo School of Economics and Finance, Queensland University of Technology, Brisbane City, Queensland, Australia
- ppppp Faculty of Education, Psychology and Art, University of Latvia, Riga, Latvia
- qqqqq Kieskompas (Election Compass), Amsterdam, Netherlands and Department of Political Science & Annenberg School for Communication, University of Pennsylvania, PA, USA
- rrrrr National Institute for the Intellectually Disabled and Autistic (NIIDA), Society for the Welfare of the Intellectually Disabled (SWID Bangladesh), Dhaka, Bangladesh
- sssss Department of Psychology, University of Münster, Münster, Germany
- ttttt Department of Communication and Media Use, Friedrich Schiller University Jena, Jena, Germany
- uuuuu Department of Social Policy and Intervention, University of Oxford, Oxford, UK
- vvvvv Department of Media and Communications, University of Sydney, Sydney, New South Wales, Australia
- wwwww Medical School, Department of Psychiatry, University of the Witwatersrand, Johannesburg, Republic of South Africa
- xxxxx Department of Psychology, University of Waterloo, Waterloo, Ontario, Canada
- yyyyy Department of Nursing, University of Huelva, Huelva, Spain
- zzzzz Department of Psychology, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
- aaaaaa Department of Psychology and Neuroscience, College of Arts and Sciences, University of Colorado Boulder, Boulder, CO, USA
- bbbbbb Department of Experimental Psychology, University of Regensburg, Regensburg, Germany
- cccccc Kyiv School of Economics, Kyiv, Ukraine
- dddddd Department of Management and Engineering, Linköping University, Linköping, Sweden
- eeeeee University of Helsinki, Helsinki, Finland
- fffff Turner Institute for Brain and Mental Health, Monash University, Clayton, Victoria, Australia
- gggggg Department of Business and Media Psychology, Ansbach University of Applied Sciences, Ansbach, Germany
- hhhhhh Center for Leadership and People Management, Ludwig Maximilian University of Munich, Munich, Germany
- iiiiii Department of Marketing, Boston University, Questrom School of Business, Boston, MA, USA
- jjjjj School of Psychology, Dublin City University, Dublin, Ireland
- kkkkkk Pontifical Xavierian University, Bogotá, Colombia
- llllll Seele Neuroscience, Mexico City, Mexico
- mmmmmm COIDESO-Research Center of Contemporary Thinking and Innovation for Social Development, University of Huelva, Huelva, Spain

nnnnnn School of Psychology, University of Auckland, Auckland, New Zealand
 oooooo Faculty of Economics, Maria Curie Skłodowska University, Lublin, Poland
 pppppp Department of Psychology, City University of New York (CUNY) Graduate Center, New York, NY, USA
 qqqqqq Department of Psychology, University of Alberta, Edmonton, Alberta, Canada
 rrrrrr Australian National Centre for the Public Awareness of Science, Australian National University, Canberra ACT, Australia
 ssssss Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China
 tttttt Department for Political Behavior, Centre for Social Sciences, Budapest, Hungary
 uuuuuu Institute of Psychology, University of Silesia in Katowice, Katowice, Poland
 vvvvvv Facultad de Psicología, Complutense University of Madrid, Madrid, Spain
 wwwwww Department of Computer Science, University of Helsinki, Helsinki, Finland
 xxxxxx Department of Computer Science, Institute of Cognitive Science, University of Colorado Boulder, Boulder, CO, USA
 yyyyyy Centro de Ciências Biológicas e da Saúde, Mackenzie Presbyterian University, São Paul, Brazil
 zzzzzz Department of Psychology & Neural Science, New York University, New York, NY, USA
 aaaaaa Department of Biology, Biodiversity Unit, University of Turku, Turku, Finland
 bbbbbb School of Psychology, Environmental Psychology Department, National Autonomous University of Mexico, Mexico City, Mexico
 cccccc Department of Humanities and Life Sciences, University School for Advanced Studies, Pavia, Italy
 dddddd Department of Social Psychology, University of Amsterdam, Amsterdam, Netherlands
 eeeeeee Department of Global Economics and Management, University of Groningen, Groningen, Netherlands
 ffffff Department of Psychology, Carleton University, Ottawa, Ontario, Canada
 gggggg PLS, ENS-Ulm, Department d'Etudes Cognitives, Paris, France
 hhhhhh Africa Business School and The School of Collective Intelligence, UM6P, Rabat, Morocco
 iiiiii Social Psychology Department, University of Amsterdam, Amsterdam, Netherlands
 jjjjjj Institute of Cognitive Neuroscience, University College London, London, UK
 kkkkkk Department of Asian and International Studies, City University of Hong Kong, Kowloon Tong, Hong Kong
 llllll Department of Psychology, Susquehanna University, Selinsgrove, PA, USA
 mmmmmm Department of Social Psychology, Friedrich Schiller University Jena, Jena, Germany
 nnnnnn Department of Design, University of Antwerp, Antwerp, Belgium
 oooooo Department of Behavioral Sciences and Learning, Linköping University, Linköping, Sweden
 pppppp Department of Psychology, University of Exeter, Exeter, UK
 qqqqqq Department of Psychology, University of Koblenz-Landau, Landau, Germany
 rrrrrr Department of Speech Pathology and Audiology, University of the Witwatersrand, Johannesburg, Republic of South Africa
 ssssss Institute of Psychology, Nicolaus Copernicus University, Torun, Poland
 tttttt Rady School of Management, University of California, San Diego, CA, USA
 uuuuuu Faculty of Arts and Science, Kyushu University, Fukuoka, Japan
 vvvvvv Department of Psychology, Kadir Has University, Fatih, Istanbul, Turkey
 wwwwww Department of Psychology, Erasmus University Rotterdam, Rotterdam, Netherlands
 xxxxxx Faculty of Negotiations, Organizations and Markets, Harvard Business School, Boston, MA, USA
 yyyyyy Department of Economics, Vidyasagar College For Women, Kolkata, West Bengal, India
 zzzzzz Department of Public Administration and Sociology, Erasmus University Rotterdam, Rotterdam, Netherlands
 aaaaaaa Impact For Development, Casablanca, Morocco
 bbbbbb Department of Economics, Koc University, Sanyer, Istanbul, Turkey
 cccccc Hult International Business School, Dubai, United Arab Emirates
 dddddd Department of International Trade, Bogazici University, Besiktas, Istanbul, Turkey
 eeeeeee Department of Psychological and Social Sciences, Penn State University Abington College, Abington, PA, USA

*To whom correspondence should be addressed: Email: tomislav.pavlovic@pilar.hr

Edited By: Karen E. Nelson

Abstract

At the beginning of 2020, COVID-19 became a global problem. Despite all the efforts to emphasize the relevance of preventive measures, not everyone adhered to them. Thus, learning more about the characteristics determining attitudinal and behavioral responses to the pandemic is crucial to improving future interventions. In this study, we applied machine learning on the multinational data collected by the International Collaboration on the Social and Moral Psychology of COVID-19 ($N = 51,404$) to test the predictive efficacy of constructs from social, moral, cognitive, and personality psychology, as well as socio-demographic factors, in the attitudinal and behavioral responses to the pandemic. The results point to several valuable insights. Internalized moral identity provided the most consistent predictive contribution—individuals perceiving moral traits as central to their self-concept reported higher adherence to preventive measures. Similar results were found for morality as cooperation, symbolized moral identity, self-control, open-mindedness, and collective narcissism, while the inverse relationship was evident for the endorsement of conspiracy theories. However, we also found a non-negligible variability in the explained variance and predictive contributions with respect to macro-level factors such as the pandemic stage or cultural region. Overall, the results underscore the importance of morality-related and contextual factors in understanding adherence to public health recommendations during the pandemic.

Keywords: COVID-19, social distancing, hygiene, policy support, public health measures

Significance Statement:

Outcomes of this study suggest that morality-related factors, along with prosociality and individual characteristics related to information processing and self-control, play an important role in determining attitudinal and behavioral responses to the COVID-19 pandemic. However, a substantial variation in the predictive contribution of included variables was observed. Therefore, the role of context (both in terms of culture and stage of the pandemic) should not be underestimated. Nevertheless, this study highlighted multiple factors relevant to the prevention of COVID-19 in different stages of the pandemic and cultures, which makes it a good starting point for more complex and causal research designs.

Introduction

The COVID-19 pandemic has caused significant loss of life, commodities, jobs, and disruption of communities worldwide. As of March 2022, over 450 million infections and more than 6 million deaths have been reported globally (1). As we write this paper, the daily number of new cases worldwide exceeds one million. Given the lack of vaccination and treatment options, controlling the spread of the SARS-CoV-2 virus in its early stages depended on preventive behaviors, such as physical distancing (2) or hand and object disinfection (3, 4). While governments across the globe rushed to implement the proposed measures, many citizens resisted such change (5, 6). This is indicative of the vital role of individual characteristics in the form of attitudes, abilities, traits, and perceptions in compliance with preventive measures. Thus, decision-makers may benefit from insights from the social and behavioral sciences that could explain who will adhere to or ignore advised measures (7).

Furthermore, nations vary in the strictness of preventive measures enacted by local governments and the severity of the consequences of COVID-19: some countries report more than 100 deaths (e.g. Croatia and the UK), while others count less than one death (e.g. Bhutan and China) per 100,000 citizens (8). A recent cross-national analysis suggests that many of these excess deaths in countries like the United States are the result of weak public health infrastructure and a decentralized, inconsistent response to the pandemic (9). This raises questions of how macro-level cultural variables might be associated with citizens' health attitudes and behaviors across nations.

The scientific community responded with numerous international research collaborations aimed at explaining adherence to preventive measures from different perspectives. One group of researchers (10) focused on cultural dimensions, self-awareness emotions, trust in governmental actions, and political orientation as predictors of compliance in the United States, Italy, and Korea. They found that horizontal collectivism was the only predictor of compliance significant in all three countries. Similarly, other scholars (11) identified collectivism's role in promoting preventive behaviors. In terms of adherence to preventive measures, prosocial tendencies emerged as a significant positive predictor, while perceiving others as violating preventive measures was the most consistent negative predictor (12). Results from another study across 70 countries showed that trust in government, conscientiousness, and agreeableness predicted engaging in preventive measures, with other variables having a negligible practical impact (13). As research accumulates, interpreting and integrating findings from diverse research streams with a variety of measures and samples presents another challenge for both scholars and practitioners.

Due to their freedom of theoretical constraints, data-driven approaches might offer solutions to “grand challenges” of existing theories, defined as complex problems with intertwined and evolving underlying mechanisms (14) as they allow the effective use of highly dimensional data (15). For instance, network analysis was used on data from the UK and the Netherlands to explore the relationship between multiple constructs relevant for COVID-19 attitudes and behaviors (16). The perceived level of adherence to norms and efficacy of preventive measures and support for these measures exhibited the strongest relationships with COVID-19 preventive behaviors. On the other hand, applying random forests on more than 100 potentially relevant variables established different descriptive and injunctive norms and prosociality

as some of the most relevant predictors of behaviors (17). Overall, the relevance of prosociality and collectivism, both of which imply a willingness to make sacrifices for the benefit of the community, has been emphasized throughout the literature (10–12, 17–19). However, this does not eliminate the role of other individual differences and capacities in adherence to preventive measures (13, 17).

Our study expands on and contributes to the existing literature in three important ways. Firstly, we brought together a diverse team of experts to select several key constructs from social, moral, cognitive, and personality psychology that might be relevant to supporting public health recommendations. Despite a proliferation of studies on predictors of attitudinal and behavioral responses to the COVID-19 pandemic (see, for example, (20)), research in this field is still warranted. Hence, we sought to investigate attitudinal and behavioral responses in the first pandemic wave, when uncertainty regarding the spread of the virus dominated societies. In conjunction with the existing findings, our study provides valuable evidence which can be utilized to compare pandemic responses from different time points during the pandemic. Moreover, we sought to statistically test the association between the three related but distinct outcomes—maintaining physical hygiene, avoiding physical contact, and supporting governmental policies related to COVID-19. This distinguishes our approach from prior research that employed a general factor of preventive behaviors as it allowed us to gain insights both into attitudinal and behavioral responses to the measures aimed at mitigating the spread of the virus. Second, we consider potential cultural differences in the meaning of the studied constructs by establishing equivalence of factor scores through (partial) strong invariance (see (21)). Finally, to determine the efficacy of our independent variables in explaining contact avoidance, hygiene maintenance, and COVID-19 policy support in each country, we applied random forest-based regression algorithms appropriate for complex data sets with possible nonlinear and interactive relationships between variables (22, 23).

Overview

We focused on two specific research questions utilizing a large international sample of 51,404 participants from 69 countries from all continents except Antarctica. First, we tested how precisely (in terms of the explained variance) avoiding contact, maintaining hygiene, and policy support could be predicted using a combination of variables from moral, social, personality, and cognitive psychology, as well as socio-demographic variables. Second, we tested which of the included variables provided a substantial contribution to the accuracy of our predictions. Descriptions of the expected effects (of all study variables) based on theories or earlier studies are available as Supplementary Materials A. (All supplementary files can be found online in the following OSF folder: https://osf.io/cvkyr/?view_only=c88c0431224c4f878750875e599d2983.) Additionally, to evaluate the robustness of our findings, we conducted additional analyses that took cultural differences and the pandemic stage during data collection into account.

Materials and Methods

International collaboration on the social and moral psychology of COVID-19 project

The aim of the International Collaboration on the Social and Moral Psychology of COVID-19 (ICSMP COVID-19) project is to

examine and understand psychological factors related to the COVID-19 pandemic response. We launched the project in April 2020 via a social media call for national teams that could collect samples in their own country. Over 230 scholars responded to the call. The main questionnaire, created in English, was disseminated to each national team, responsible for translating it to their local language (using the standard forward-backwards method). Each team collected the data in their own country. The resulting datasets were then collated and analyzed altogether, and are available online (19, 24). The study received an umbrella ethics approval from the University of Kent.

Participants

The analyzed sample consisted of 51,404 participants from 69 countries and territories, 25 of which collected samples representative of their respective nations regarding age and gender ($n = 22,064$). The remaining data were drawn from convenience samples. Following exclusion criteria set for the purposes of this study (we excluded participants providing inaccurate response to the attention check, participants who did not provide responses to more than one quarter of items, participants providing the same response more than ten times in a row on the items of our predictors, participants who chose “other” as their gender* and participants completing the questionnaire unusually fast or unusually slow, see Supplementary Materials B and C), 7,615 participants were removed, resulting in a sample of 43,789 ($M_{\text{age}} = 43$, $SD_{\text{age}} = 16$; 52% females) participants for our analyses (The number of participants who chose “other” as their gender was too low in the context of planned analyses).

Measures

Unless otherwise indicated, participants responded on an 11-point scale with higher values indicating higher levels of the measured concepts (after reversing the appropriate items). Prior to conducting analyses that presumed grouping of participants, we achieved partial strong invariance for all of the included multi-item scales. This was important to ensure that we measured the same constructs with similar efficacy in each group (see (21)). Detailed output on how the fit was achieved can be found in Supplementary Material C.

Individual-level variables

Criteria

Avoidance of physical contact during the coronavirus (COVID-19) pandemic was measured via five items. Adequate fit ($CFI = 0.979$, $RMSEA$ (95% CI upper limit) = 0.086, $SRMR = 0.024$, and $\omega^2 = 0.69$) was achieved after correlating the residuals of the last two items (keeping distance and avoiding handshakes).

Maintaining physical hygiene was measured via five items related to washing hands and other behaviors related to personal hygiene. A single factor structure was retained ($CFI = 0.999$, $RMSEA$ (95% CI upper limit) = 0.037, $SRMR = 0.007$, and $\omega^2 = 0.74$) with correlated residuals of the first two items (washing hands longer and more thoroughly).

Support for COVID-19-related policy decisions was measured with five items relating to restrictive policies affecting five areas of everyday life. A single factor structure was retained ($CFI = 0.989$, $RMSEA$ (95% CI upper limit) = 0.098, $SRMR = 0.016$, and $\omega^2 = 0.86$)

after correlating residuals of support for forbidding public gatherings and unnecessary travel, and closing parks.

Predictors

Morality

Moral identity was measured using the 10-item moral identity scale (25). The original paper reports a two-factor model (Internalization and Symbolization), with acceptable internal consistency. The two-factor structure was confirmed in our study after correlating residuals of items 8 and 9, and 4 and 7 ($CFI = 0.939$, $RMSEA$ (95% CI upper limit) = 0.084, $SRMR = 0.067$, $\omega^2_{\text{internalization}} = 0.68$, and $\omega^2_{\text{symbolization}} = 0.75$).

The moral circle scale (26) assesses the moral expansiveness across 16 different entities (human and nonhuman) deemed worthy of moral concern. Participants indicated the extent of their moral circle, i.e. the circle for which they are concerned about right and wrong done towards them, ranging from immediate family to all things in existence.

Morality as cooperation was measured using the Relevance subscale of the Morality-as-Cooperation Questionnaire (MAC-Q; (27)), which measures the extent to which each of the seven dimensions of cooperation is relevant when making moral judgments. One item per each of its seven dimensions was used in this study. After excluding the items of fairness and property and correlating residuals between *helping a family member* and *showing courage* and *helping a family member* and *uniting a community*, a general factor of the relevance of cooperation in morality ($CFI = 0.991$, $RMSEA$ (95% CI upper limit) = 0.066, $SRMR = 0.014$, and $\omega^2 = 0.73$) was extracted.

(Pro)social identification and attitudes

National identity was assessed with two items combined into a scale: “I identify as [nationality]” (28) and “Being a [nationality] is an important reflection of who I am” (see (29)). The correlation among items was $r = 0.69$, and a single score was extracted using PAF.

Social belonging was measured using a four-item single-factor scale with excellent internal consistency (30). A single factor structure ($CFI = 0.988$, $RMSEA$ (95% CI upper limit) = 0.115, $SRMR = 0.017$, and $\omega^2 = 0.78$) was confirmed in this study after correlating the residuals between first and third item.

Collective (national) narcissism was measured using three items of the original, single-factor Collective Narcissism scale (31). Invariance of this scale was tested along with the endorsement of COVID-19 conspiracy theories (32), which was measured using a single item for a denial conspiracy and three items for deflection conspiracies (e.g. “a hoax invented by interest groups for financial gains”). The three items related to collective narcissism and the four items related to belief in conspiracy theories were modeled together and yielded a clear two-factor structure ($CFI = 0.988$, $RMSEA$ (95% CI upper limit) = 0.069, $SRMR = 0.021$, $\omega^2_{\text{Conspiracies}} = 0.92$, and $\omega^2_{\text{Collective narcissism}} = 0.87$).

Political orientation was measured using a single item, “Overall, what would be the best description of your political views?,” on a scale ranging from very left-leaning (“0”) to very right-leaning (“10”).

COVID-19 risk perception was measured with two items asking participants to rate how likely it was for them and for the average person to get infected with COVID-19 by 2021 April 30, on a slider scale ranging from 0 (“impossible”) to 100 (“certain”). Based on their high correlation ($r = 0.66$), a single component was extracted using PAF.

Individual dispositions

Individual grandiose narcissism was measured using the brief version of the Narcissistic Admiration and Rivalry Questionnaire (33), comprising two subcomponents, rivalry (R) and admiration (A), which exhibited acceptable internal consistency. The scale achieved acceptable fit after correlating residuals between items 3 and 6 reflecting rivalry (CFI = 0.986, RMSEA (95% CI upper limit) = 0.068, SRMR = 0.020, $\omega^2 = 0.69$ for admiration, and $\omega^2 = 0.55$ for rivalry).

Trait self-control was measured as a single-factor four-item scale (34), with the last two items being negatively worded. However, an adequate fit was not obtained even after correlating residuals of the first two items (CFI = 0.988, RMSEA (95% CI upper limit) = 0.115, SRMR = 0.017, and $\omega^2 = 0.78$).

Self-esteem was measured using the Single-Item Self-Esteem-Scale (SISE), which achieved good test-retest reliability and was established as a viable alternative of longer self-esteem scales (35).

Trait optimism was measured using two items from the three-item optimism subscale of the Life Orientation Test-Revised (36). Based on their high correlation ($r = 0.71$), a single factor was retrieved using PAF.

Open-mindedness, reflecting the acceptance of limitation of one's knowledge and willingness to gain new knowledge, was measured with a six-item scale of the Multidimensional measure of intellectual humility (37). The originally proposed single-factor structure achieved an acceptable fit in our study (CFI = 0.998, RMSEA (95% CI upper limit) = 0.025, and SRMR = 0.007) and was retained. It exhibited questionable internal consistency ($\omega^2 = 0.50$).

Cognitive reflection was measured with a three-item test that measures the ability to inhibit intuitive answers and engage in reflection to provide correct ones, adapted from Frederick (38). Correct answers were coded as "1" and incorrect as "0," with a total scale ranging from 0 to 3.

Demographic factors and experiences

The MacArthur Scale of Subjective Social Status (39) was used to measure subjective socio-economic status by asking participants to place themselves on an 11-rung ladder, with the top rung representing individuals who are best off (in terms of education, jobs, and wealth), and the bottom rung the ones worst off.

Participants were asked whether they had (coded as "1") tested positive for COVID-19 and/or had a close relative or acquaintance (friend, partner, family, colleague, and so on) who had tested positive for COVID-19 ("1") or not ("0") by the time of data collection.

Multiple demographic factors were also collected. Participants were asked to indicate whether they identify as "male," "female," or "other" and enter their age (in years). Additionally, participants' marital status had the following three options: married, single, in a relationship (recoded into married or in a relationship ("1") or other ("0")), after which they indicated the number of children they had. Participants were also asked to indicate their employment status (recoded into the employed, students, or retired ("1") or other ("0")). Finally, participants indicated whether they lived in an urban (coded as "1") or rural setting (coded as "0").

Analytical procedure

This study was not preregistered. Our analytical approach consisted of multiple steps (see Supplementary Materials B–F) conducted in R (40). A detailed description of data cleaning is presented in Supplementary Material B, while used packages are

listed at the beginning of every Supplementary Material in which they were used.

The psychometric properties of the applied measures were tested on the imputed data (see Supplementary Material C). We focused on testing the applied measures' factor structure and internal consistency. As the majority of the multi-item measures were taken from previously validated instruments, CFAs with robust maximum likelihood estimator (MLR; (41, 42)) and countries as clusters were applied using lavaan (43) to test whether the proposed structures fit to the overall data. Modification indices were consulted when theoretical models did not fit the data well.

We tested whether the obtained results were stable concerning the pandemic stage during data collection. In the absence of any specific criterion, we initially attempted to group countries according to the total number of COVID-19 cases per million inhabitants during the period of data collection, calculated as the average of the number of cases per million at the start date of data collection and the number of new cases per million at the end date of data collection (<https://github.com/CSSEGISandData/COVID-19>). In samples where only one date was provided, we used the available information for that date. However, we noticed an unwanted regularity in the grouping process—most countries with the total number of cases above the median were European countries, and no countries from Africa were in this group. Thus, to minimize potential cultural biases, we grouped the countries according to the Inglehart–Welzel cultural map (44) and selected the countries with the lowest and highest total number of cases per million from each cultural region (Orthodox European countries, Protestant European countries, Catholic European countries, English-Speaking countries, West and South Asian countries, Confucian countries, African-Islamic countries, and Latin American countries) as representative. This resulted in a group of countries in the early stage of the pandemic consisting of participants from Nigeria, Slovakia, Australia, Bulgaria, the Philippines, and Nepal. On the other hand, a group of countries in the advanced pandemic stage included participants from United Arab Emirates, Spain, Ireland, Serbia, Brazil, and Singapore. Regarding Latin American countries, we considered only countries with more than 150 participants as candidates, while no Protestant European countries were included due to all of them being in the advanced stage of the pandemic during the data collection period (with a total number of citizens infected per million exceeding 1,000). Our two groups were highly distinctive with respect to the total number of cases per million during the data collection ($M_{\text{early stage}} = 154.14$; $M_{\text{advanced stage}} = 3520.87$). In our attempt to further balance the analysis, we randomly selected the same number of participants from each selected country, equal to the size of the smallest included sample after the data cleaning ($n_{\text{UAE}} = 176$).

Then, we checked the cross-group invariance of our multi-item measures. (We also conducted analyses with groups reflecting regions of the Inglehart–Welzel cultural map (2020), which followed the described procedure. Due to space limitations, outputs of these analyses can be found in Supplementary Materials G.) After achieving an adequate fit by introducing changes suggested by modification indices, the cross-group invariance of each obtained theoretical model was tested. Stepwise tests were further conducted. First, configural models were formed for each construct, followed by models with constrained item loadings to test weak invariance, and ultimately models with constrained item loadings and intercepts to test strong invariance. If the configural model achieved adequate fit, successive changes in fit indices with respect to imposing restriction were used as a criterion for

invariance. A CFI change of -0.015 accompanied by a change in RMSEA or SRMR of $+0.015$ was considered as an indication of achieving a higher level of invariance. If invariance was not achieved on the first attempt, modification indices were consulted to achieve partial invariance. Finally, we extracted factor scores from models reflecting strong invariance (where loadings and intercepts were constrained to form comparable scores across countries) using the ten Berge correction to use them in further analyses.

Because two-item measures cannot be tested using CFA, factor analyses using principal axis factoring were conducted to extract latent dimensions. In line with the factor scores based on strong invariance, the analyses were conducted on the entire dataset used in a specific analysis.

Socio-demographic characteristics and moral circle were not scaled. Variables absent from a specific national data set were replaced with a constant (i.e. the number of children in the Ghanaian data set was set to median of other countries, while the residence data was coded as urban for participants from Canada and Bulgaria).

The rest of the procedure was similar to the procedure applied by Van Lissa et al. (17). After data preparations, random forests were applied. Ranger function (45) was used to apply random forests that served as a basis for partial dependence plots and permutation importance metrics (see (46)), which were used to interpret the relationships (see Supplementary Material D). Regarding the hyperparameters, the number of trees was set to 1,000 and 2,000, R^2 was chosen as the accuracy metric, permutation importance metrics were extracted as estimated variable importance, the number of variables to test at each split ranged from five to twenty with an increment of one, splitting was based on variance, while the minimum node sizes ranged from 3 to 99 with an increment of three. Holdout sample was used to ensure the robustness of findings: 20% of the sample from each country formed a test set on which R^2 and variable importance metrics (see Supplementary Materials E and F) were calculated.

Results

Obtained R^2 values of optimally tuned models were of weak to moderate magnitude both on the complete data ($R^2_{\text{contact}} = 0.134$, $R^2_{\text{hygiene}} = 0.200$, and $R^2_{\text{policy}} = 0.146$) and data consisting of samples nationally representative regarding age and gender ($R^2_{\text{contact}} = 0.172$, $R^2_{\text{hygiene}} = 0.256$, and $R^2_{\text{policy}} = 0.124$). In the early stage of the pandemic, prediction of contact avoidance was negligible ($R^2_{\text{contact}} = 0.045$, $R^2_{\text{hygiene}} = 0.272$, and $R^2_{\text{policy}} = 0.138$). On the other hand, in the advanced stage of the pandemic, our models led to a very imprecise prediction of maintaining hygiene ($R^2_{\text{contact}} = 0.129$, $R^2_{\text{hygiene}} = -0.043$, $R^2_{\text{policy}} = 0.173$). Therefore, we decided not to interpret the predictive contributions in models with maintaining hygiene as the criterion on the sample reflecting the advanced stage of the pandemic. Nevertheless, they are presented in the following paragraphs.

Results in Fig. 1 show the importance metrics based on the models that yielded the highest R^2 per analysis. As permutation importance reflects a reduction in error, these plots are not directly comparable. However, some common patterns can be observed.

In terms of avoiding contact (Fig. 2), internalized moral identity provided the most consistent contribution across analyses, followed by open-mindedness, collective narcissism, morality as cooperation, symbolized moral identity, and self-control. Endorse-

ment of conspiracy theories seems to have exhibited a stronger relationship with our criteria in the early stage of the pandemic than in the advanced stage. In general, participants achieving higher scores on avoiding contact also achieved higher scores on internalized moral identity, morality as cooperation, self-control, and open-mindedness, respectively. These participants also exhibited lower endorsement of conspiracy theories. Regarding collective narcissism and symbolized moral identity, it seems that the individuals scoring around the midpoint reported higher contact avoidance compared to individuals scoring high and those scoring low on the scale.

Regarding hygiene maintenance (Fig. 3), the most invariable contribution was found for social belonging and morality as cooperation, followed by internalized and symbolized moral identity, collective narcissism, and self-control. Gender differences in hygiene maintenance found on the complete data and data based on representative samples were not detected in data organized according to the stage of pandemic. Participants scoring higher on social belonging, internalized and symbolized moral identity, collective narcissism, and self-control also scored higher on maintaining hygiene. However, only the relationship between belonging and hygiene maintenance seemed linear—all other lines reached a plateau at some point (usually around the midpoint), indicating participants achieving the lowest scores on these factors also achieved the lowest scores on maintaining hygiene. On the other hand, higher scores were related to higher reported hygiene maintenance among participants scoring above the mean of morality as cooperation.

The most invariable predictors of policy support (Fig. 4) were collective narcissism, internalized moral identity, and self-control. Endorsement of conspiracy theories, symbolized moral identity, possibly even morality as cooperation, and open-mindedness, seem to have exhibited a stronger relationship with policy support in the early stages of the pandemic compared to the advanced stage. Participants scoring higher on internalized moral identity and self-control generally were also more supportive of policy measures. However, the relationships were not linear in the early pandemic stage (and in the advanced stage in the context of self-control). The relationship between policy support and collective narcissism was also complex—it was close to linear and positive in the advanced pandemic stage, but in the early stages and on the complete data, it resembled an inverted-U-curve with a peak around the mean. This indicates that participants scoring around the mean were most supportive of restrictive policies, while those high and the ones low on collective narcissism were less supportive. Participants showing more endorsement for COVID-19 conspiracy theories were less supportive, while participants scoring higher on open-mindedness were more supportive of restrictive COVID-19 policies. The relationship between morality as cooperation and policy support was established only on the complete data and indicated that only among those above the mean higher morality as cooperation was related to higher policy support. The opposite was found for symbolized moral identity—only among those lowest on this trait, the relationship between morality as cooperation and policy support was linear and positive. No relationships were established around the mean or above the mean.

Discussion

Taking the machine learning approach, we provided several insights into social, psychological, personality, and cognitive factors in predicting COVID-19 responses. Although the nature of the

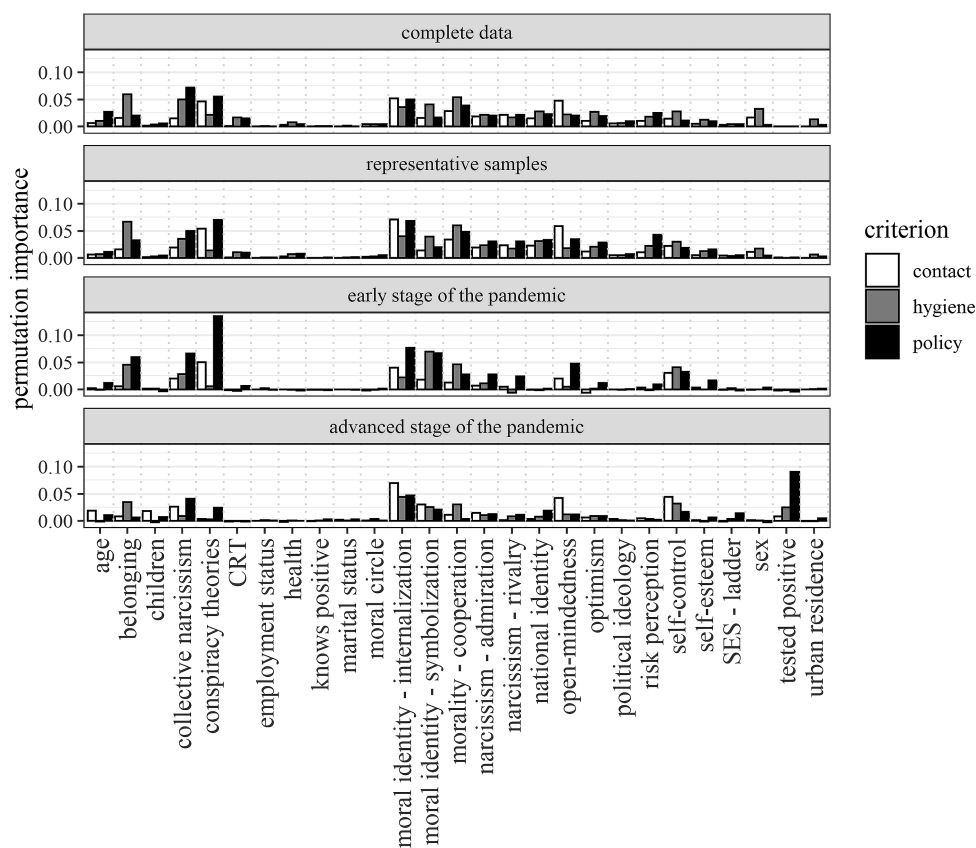


Fig. 1. Permutation variable importance calculated with respect to representativeness of the samples and stage of the pandemic.

analyses (i.e. the dependence of importance estimates on error estimates, which changes across models) prevents us from direct comparisons of results across models, some consistent patterns were observed.

Internalized moral identity was the most consistent predictor of COVID-19 attitudinal and behavioral responses—the extent to which people perceived moral traits as central to their self-concept was positively associated with their intentions to avoid physical contact, maintain hygiene, and support policy measures aimed at mitigating the spread of the virus. Morality-as-Cooperation was also associated with the attitudinal and behavioral responses, most consistently in predicting hygiene maintenance. These results suggest that maintaining hygiene, but also physical distancing and policy support, were perceived as collective actions that benefit the group more than they benefit the self. Symbolized moral identity was also associated with the criteria, but, interestingly, the relationship was nonlinear and strongest among participants scoring below the average of symbolized moral identity. These findings may reflect the fact that individuals characterized by moderate or high symbolization of moral identity prefer to be perceived as aligned with social norms, rather than actually adhering to them (47). However, the threshold at which the relationship becomes linear seems to change with respect to the pandemic stage and specific criteria, indicating the need for further research into these relationships.

Overall, these findings are in line with previous research suggesting that internalized moral identity is a relevant predictor of prosocial and cooperative intentions and behavior, with more inconsistent results when examining the symbolization dimension of moral identity (for a review, see (47, 48)). The only variable re-

lated to morality that did not substantially contribute to our criteria's prediction was the moral circle. Altogether, these results indicate that morality represents an important factor in adherence to preventive measures. Nevertheless, different aspects of morality provide different contributions to the prediction of adherence to these measures.

Open-mindedness and self-control were positively associated with avoiding contact and supporting policy, while self-control also exhibited a relatively steady, albeit weak, contribution to the prediction of hygiene maintenance. Open-mindedness was conceptualized as a part of cognitive humility, which reflects the virtue of being able to accept one's fallibility and the willingness to accept information contrary to one's initial beliefs (37, 49), with some authors treating it as a moral virtue (50, 51). Self-control is typically conceptualized as the capacity to work effectively to reach goals, resisting short-term temptations (34, 52). Some authors have suggested that self-control goals are often moralized (53). The relationship between open-mindedness and morality and between self-control and morality may underlie the predictive contribution of open-mindedness and self-control established in this study.

Social belonging was also established as a relevant predictor predominantly in terms of maintaining hygiene, while collective narcissism also provided a substantial contribution to predicting policy support and a less substantial contribution to predicting contact avoidance. On the one hand, ingroup identification promotes acceptance of group norms (54), implying that findings on social belonging could also reflect morality. On the other hand, the relationship between collective narcissism and our criteria seems to be more complex, in line with the mixed evidence of

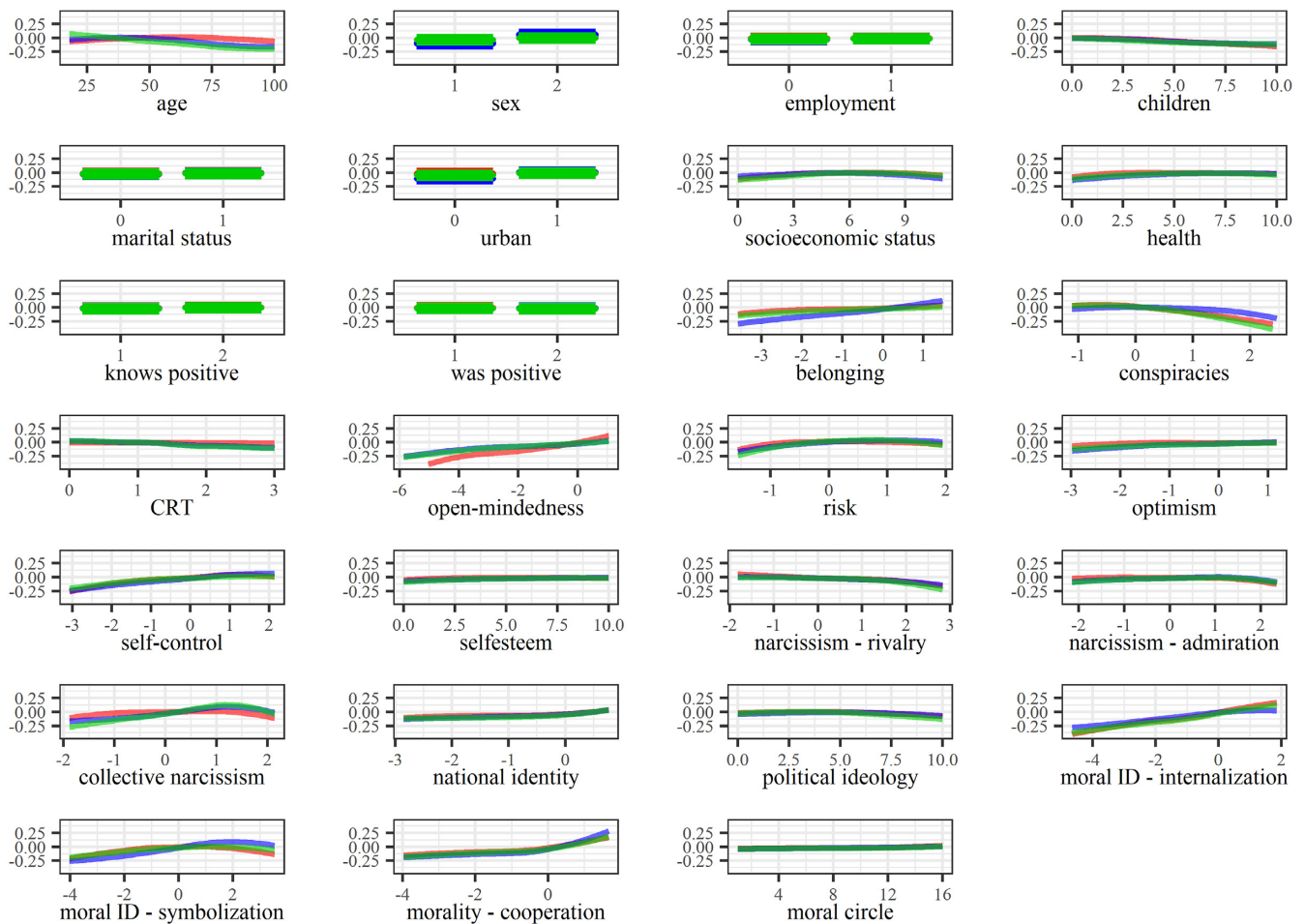


Fig. 2. Partial dependence plots depicting the relationships between our predictors and criteria based on the complete data. Note: red, blue, and green represent avoiding contact, maintaining hygiene, and policy support, respectively.

previous studies on the role of collective narcissism concerning various types of preventive behaviors such as handwashing, physical distancing, and limiting leaving home (32, 55). Namely, the evidence of a curvilinear relationship between collective narcissism and contact avoidance and policy support might reflect the need of individuals high in collective narcissism to establish and maintain a positive national image for the outside world (e.g. as model citizens, or morally superior) (56, 57). However, at even higher levels of collective narcissism, the need to assert and signal grandiosity and superiority in relation to various threats (in this case, the virus) might manifest in lower support for restrictive preventive measures, even at the cost of possible negative consequences for ingroup members (58, 59). This is also evident from the inverted-U curve in the context of policy support, usually appearing slightly above the mean (except in the late stage of the pandemic, see Figs. 2 and 3). Overall, this suggests that while believing in ingroup potential may motivate individuals to adhere to prosocial norms, irrational belief in superiority can undermine the support for preventive measures that bring about short-term disturbance in the everyday ingroup dynamics.

Additionally, conspiracy beliefs seem to be linked to contact avoidance and policy support, especially in the early stage of the pandemic. Namely, endorsement of COVID-19 conspiracy theories was associated with lower intentions to engage in physical distancing and lower policy support. Given that conspiracy believ-

ers were found to be more self-centered (60) and less generous (61) during the COVID-19 pandemic, this finding speaks in favor of viewing contact avoidance as a form of prosocial action.

The presented findings suggest that prosociality and morality are relevant factors for understanding physical distancing. This is in line with previous work on the role of prosociality on physical distancing (e.g. (10, 12, 17); see (18) for a review) and with the idea that personal norms, internal standards on what is right or wrong in a given situation, play an important role in driving prosocial behavior ((62, 63); see (64), for a review). However, our results indicated a substantial contextual variability, as well. While we focused on several most dependable and most substantial predictors only to describe general patterns, it should be noted that multiple other factors provided a contribution limited to a specific stage of the pandemic or specific culture (see Supplementary Materials G). This also implies that campaigns for increasing compliance with preventive measures in future crises should be tailored to both the pandemic phase and the specifics of the culture in which they plan to be implemented. Additionally, the results of our study suggest that psychological factors are more relevant than demographics in the context of health-related crises and should not be neglected when tailoring preventive measures.

Generally, the obtained R^2 values were lower than those reported by Van Lissa et al. (17) in similar analyses. In their study, injunctive norms and support for COVID-19 restrictive measures

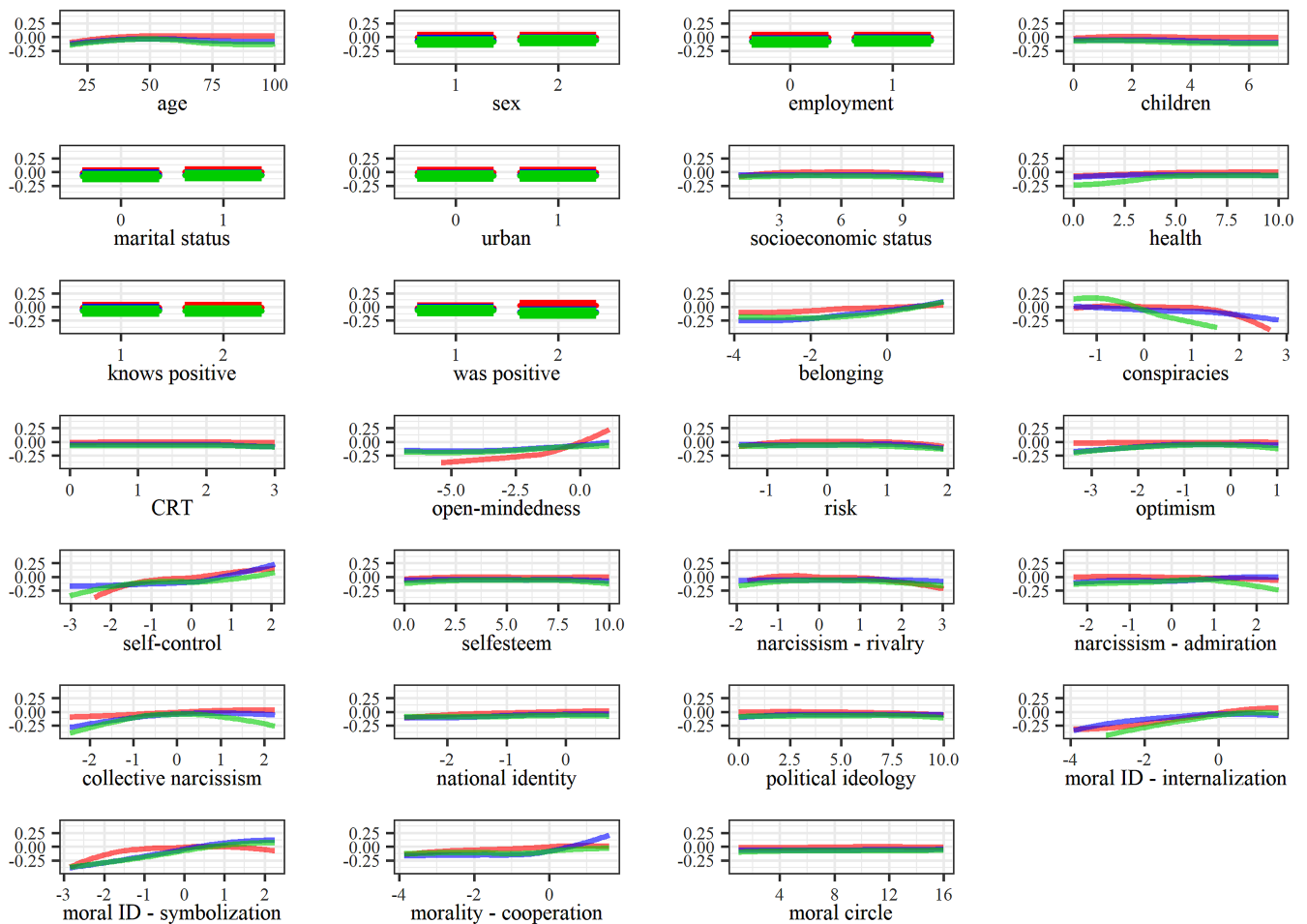


Fig. 3. Partial dependence plots based on the data reflecting the early stage of pandemic.
Note: red, blue, and green represent avoiding contact, maintaining hygiene, and policy support, respectively.

were found to be two clearly dominant predictors of preventive behaviors, which may roughly approximate two aspects of the Theory of Planned Behavior (65)—subjective norms and attitudes on the specific behavior. We did not include these variables in our study, although policy support could broadly be considered as attitudes regarding preventive measures. Conversely, we treated policy support as one of the criteria rather than as one of the predictors, with contact avoidance, hygiene maintenance, and policy support being moderately correlated ($r = \text{approx. } 0.40$). Thus, the simplest explanation of the difference in the explained variance in our study compared to Van Lissa et al. (17) may reflect the difference in the extent to which the Theory of Planned Behavior has been represented among predictors. Considered together, the two studies provide evidence in favor of the Theory of Planned Behavior in the context of a global crisis.

Several limitations should be considered when interpreting our findings. First, not all the national samples were representative, and even the representative samples were not based on probabilistic sampling, and consequently, some segments of society may have been underrepresented. Furthermore, as the study was conducted online, our sample over-represents people with greater access to internet-enabled technology, which may be a particularly important consideration in less-developed countries (e.g. dissemination of conspiracy theories and fake news). Second, variability in our criteria was heavily skewed in many countries (i.e. the vast majority of participants reported high adherence to and

support for preventive measures), which can be attributed to the first wave of the pandemic during which the data were collected. Nevertheless, in some countries, data collection was conducted during the peak of the first wave of the COVID-19 pandemic, while in other countries, it was carried out at its beginning. Although we tried to operationalize the pandemic stage according to the total number of infected individuals per million and took culture and sample size into account, even such operationalization may not have eliminated all the potential sources of bias. The rough similarity of the results based on representative and nonrepresentative data, as well as data from countries in different pandemic stages and data from countries grouped according to cultural zones (see Supplementary Materials G), provide arguments in favor of the validity of our findings; nevertheless, the robustness of these more specific findings needs to be corroborated utilizing different (i.e. longitudinal and nationally representative) samples. Furthermore, Morality-as-Cooperation had to be modeled differently than proposed in the original papers to achieve invariance. Additionally, as there are no conventional methods of testing the invariance of two-item and single-item measures across cultures, scores on such items may be less precisely calculated than in the case of multi-item measures. Finally, we focused on explaining variation in COVID-19 responses without testing causality. It should be noted that we used cross-sectional, self-reported data which may entail the desirability bias risk (66). However, there is evidence that such desirability bias does not play a key role,

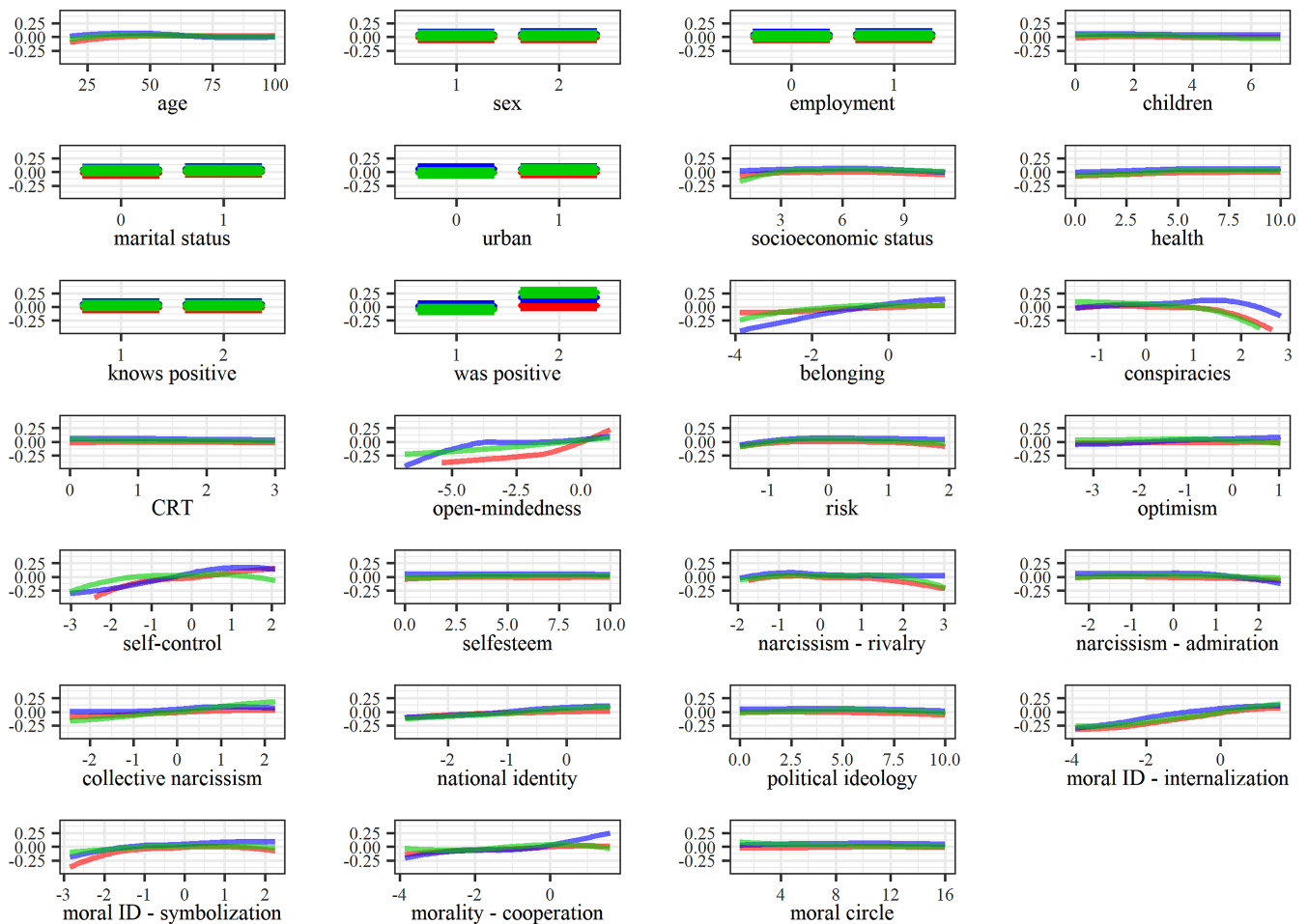


Fig. 4. Partial dependence plots based on the data reflecting the advanced stage of pandemic. Note: red, blue, and green represent avoiding contact, maintaining hygiene, and policy support, respectively.

especially in self-reported measures like self-esteem, control, or optimism (67).

Conclusion

Findings of our study indicate that the most effective predictors of COVID-19 responses, such as avoiding physical contact, maintaining hygiene, and supporting restrictive COVID-19 policies, were related to morality, prosociality, and traits and attitudes operationalizing self-control and information processing. However, the predictive contribution of even the most invariant predictors substantially varied with respect to the predicted type of response and cultural characteristics. While the research design of this study prevents any causal conclusions, the results suggest that the interplay between individual and contextual characteristics is relevant for understanding individual COVID-19 responses. Ultimately, our findings can serve as a starting point for future, more nuanced, research on the variables highlighted within our study. Hopefully, the growing body of research and accumulated insights should lead to informed and efficient prevention and intervention programs for health-related crises.

Supplementary Material

Supplementary material is available at [PNAS Nexus](https://www.pnas.org) online.

Funding

E.L. was financially supported by the VolkswagenStiftung (grant no. 98 525). Manos Tsakiris was financially supported by the NOMIS Stiftung (NOMIS Foundation). O.B. was financially supported by the Slovak Research and Development Agency (SRDA; Agentúra na podporu výskumu a vývoja; grant no. APVV-18-0218). P.L. was financially supported by the Medical Research Council (MRC; grant no. MR/P014097/1) and the Economic Social Research Council Impact Acceleration Award, University of Oxford. M.B.P. was financially supported by the Carlsberg Foundation (grant no. CF20-044). Michael Tyralla was financially supported by the HKUST IEMS research grant project, funded by EY. R.A.Z. was financially supported by the Netherlands Organization for Scientific Research (NWO; grant no. 440.20.003). Z.P. was financially supported by the Ministry of Education, Science, and Technological Development of the Republic of Serbia (grant no. 451-03-9/2021-14/200163). Y.Z. was financially supported by the National Natural Science Foundation of China (grant no. 71972065; 71832004; and 71872152), Universities in Hebei Province Hundred Outstanding Innovative Talents Support Program (grant no. SLRC2019002); and the Ministry of Education in China (grant no. 21JHQ088). B.S. was financially supported by the French National Research Agency (ANR; grant no. ANR-10-IDEX-0001-02 PSL*, ANR-10-LABX-0087 IEC, and ANR-17-EURE-0017 FrontCog). J.C. was financially supported by the IAST funding from the French National Research Agency

(ANR) under the Investments for the Future (Investissements d'Avenir) programme (grant no. ANR-17-EURE-0010). M.H. was financially supported by the Slovak Research and Development Agency (grant no. APVV-17-0596). M.M. was financially supported by the Institute of Social Sciences Ivo Pilar, Zagreb; Croatia. T.P. was financially supported by the Institute of Social Sciences Ivo Pilar and Croatian Science Foundation (grant no. DOK-01-2018), Zagreb; Croatia. I.M. was financially supported by the Institute of Social Sciences Ivo Pilar, Zagreb; Croatia. R.F. was financially supported by the Institute of Social Sciences Ivo Pilar, Zagreb; Croatia. A.I. was financially supported by the grants from Takeda (CW2680521); CONICET; ANID/FONDECYT Regular (1210195 and 1210176); FONCYT-PICT 2017-1820; ANID/FONDAP/15150012; Sistema General de Regalías (BPIN2018000100059), the Universidad del Valle (CI 5316); and the Multi-Partner Consortium to Expand Dementia Research in Latin America [ReDLat, supported by the National Institutes of Health, the National Institutes of Aging (R01 AG057234), the Alzheimer's Association (SG-20-725707), the Rainwater Charitable foundation—Tau Consortium, and the Global Brain Health Institute]]. P.S.B. was financially supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES; grant no. 1133/2019) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; grant no. 309905/2019-2). G.G.R. was financially supported by the São Paulo Research Foundation (grant no. 2019/26665-5). W.M.S. was financially supported by the São Paulo Research Foundation—FAPESP (grant no. 2019/27100-1). R.M.R. was financially supported by the Australian Research Council (grant no. DP180102384). M.A. was financially supported by the John Templeton Foundation (grant no. 61378). H.H.T. was financially supported by the Ministry of Science and Technology, Taiwan. M.-J.L. was financially supported by the Ministry of Science and Technology, Taiwan. J.J.V.B. was financially supported by the John Templeton Foundation. U.D. was financially supported by the QUT Centre for Behavioural Economics, Society and Technology (BEST). A.C. was financially supported by the National Science Center (grant no. 2018/29/B/HS6/02826). S.B. was financially supported by the ANR-Labex IAST. F.C.A. was financially supported by the Research Council of Norway through its Centres of Excellence Scheme, FAIR project (grant no. 262675). B.C. was financially supported by the Social Sciences and Humanities Research Council (SSHRC). C.L. was financially supported by the Sistema Nacional de Investigadores, CONACyT (Mexico). R.T. was financially supported by the NOMIS Foundation Distinguished Scientist Award for the “Body & Image in Arts & Science” (BIAS) Project. T.O. was financially supported by the Aarhus University Research Foundation (grant no. 28207). D.S. was financially supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the Germany's Excellence Strategy (grant no. EXC 2052/1-390713894). M.A.J.A. was financially supported by the Biotechnology and Biological Sciences Research Council David Phillips Fellowship (grant no. BB/R010668/1). A.K. was financially supported by the Jane & Aatos Erkko Foundation (grant no. 170112) and the Academy of Finland (grant no. 323207). E.M.-M. was financially supported by the Contemporary Thinking and Innovation for Social Development (COIDESO), the University of Huelva, Huelva, Spain. T.S. was financially supported by the Jane & Aatos Erkko Foundation (grant no. 170112) and the Academy of Finland (grant no. 323207). C.L. was financially supported by the University of Vienna, COVID-19 Rapid Response grant, and the Austrian Science Fund (FWF, I3381). A.C.W. was financially supported by the Natural Sciences and Engineering Research Council of Canada. H.S. was financially supported by the Research Council of Norway, Centres of Excellence scheme -FAIR

project (grant no. 262675). S.B. was financially supported by the School of Medicine and Health Sciences—Universidad del Rosario. W.C. was financially supported by the SSHRC grant (grant no. 506547). E.B. was financially supported by the PAI2018 project PROCOPE (Prosociality, Cognition, and Peer Effects) funded by the IMT School for Advanced Studies Lucca. V.H.D. was financially supported by the SSHRC grant (grant no. 506547). P.M. was financially supported by the Aarhus University Research Foundation (grant no. AUFF-E-201 9-9-4). A.F. was financially supported by the Slovak Research and Development Agency (grant no. APVV-17-0596). S.R. was financially supported by the Gates Cambridge Scholarship. M.J.A.W. was financially supported by the Social Science and Humanities Research Council of Canada (grant no. 435-2019-0692). A.O. was financially supported by the Swedish Research Council—consolidator grant (grant no. 2018-00877). J.F. was financially supported by the Natural Sciences and Engineering Research Council of Canada. L.C. was financially supported by the Batten Institute, the University of Virginia Darden School of Business. R.B.F. was financially supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the Germany's Excellence Strategy (grant no. EXC 2052/1-390713894). Open access funding was enabled and organized by Darden School of Business, Charlottesville, VA, USA.

Authors' Contributions

Conceptualization: T.P. and J.-v.B.; data curation: T.P., F.A., W.M.S., G.G.R., and P.S.B.; formal analysis: T.P., F.A., K.D., J.R.-M., M.M., P.D.K., C.P.-G., J.K., S.R., and E.H.; investigation (data collection): all authors; methodology: T.P. and J.K.; project administration: T.P.; software: T.P., F.A., K.D., J.R.-M., M.M., P.D.K., C.P.-G., J.K., S.R., and E.H.; supervision: T.P., M.M., M.D.B., and J.v.B.; validation: T.P.; visualization: T.P., J.K., and S.R.; writing—original draft: K.D., M.M., T.G., G.H., J.K., M.D.B., P.S., V.C., H.S.-G., M.Y., A.I., S.R., E.W., D.S., J.-W.v.P., E.H., C.T.E., R.F., Z.P., and P.M.; and writing—review and editing: all authors.

Data Availability

The data that support the findings of this study are openly available in OSF at <http://doi.org/10.17605/osf.io/tfsza>. These data have been used in multiple other manuscripts, including the “National identity predicts public health support during a global pandemic” manuscript, where Professor John Nezelek conducted the main analyses.

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