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Exposure and connectedness to natural environments: An examination of the measurement invariance of the Nature Exposure Scale (NES) and Connectedness to Nature Scale (CNS) across 65 nations, 40 languages, gender identities, and age groups

Viren Swami [a,b,*], Mathew P. White [c], Martin Voracek [c], Ulrich S. Tran [c], Toivo Aavik [d], Hamed Abdollahpour Ranjbar [e], Sulaiman Olanrewaju Adebayo [f], Reza Afhami [g], Oli Ahmed [h], Annie Aimé [i], Marwan Akel [j,k], Hussam Al Halbusi [l], George Alexias [m], Khawla F. Ali [n], Nursel Alp-Dal [o], Anas B. Alsalhani [p], Sara Álvarez-Solas [q], Ana Carolina Soares Amaral [r], Sonny Andrianto [s], Trefor Aspden [t], Marios Argyrides [u], John Jamir Benzon R. Aruta [v], Stephen Atkin [n], Olusola Ayandele [w,x], Migle Baceviciene [y], Radvan Bahbouh [z], Andrea Ballesio [aa], David Barron [ab], Ashleigh Bellard [ac], SóleySesselja Bender [ad], Kerime Derya Beydağ [ae], Gorana Birovljević [af], Marie-Ève Blackburn [ag], Teresita Borja-Alvarez [ah], Joanna Borowiec [ai], Miroslava Bozogáňová [aj,ak], Solfrid Bratland-Sanda [al], MatthewH.E.M. Browning [am], Anna Brytek-Matera [an], Marina Burakova [ao], Yeliz Çakır-Koçak [ap], Pablo Camacho [aq], Vittorio Emanuele Camilleri [ar], Valentina Cazzato [ac,as], Silvia Cerea [at,au], Apitchaya Chaiwutikornwanich [av], Trawin Chaleeraktrakoon [aw], Tim Chambers [ax], Qing-Wei Chen [ay,az], Xin Chen [ba], Chin-Lung Chien [bb], Phatthanakit Chobthamkit [aw], Bovornpot Choompunuch [bc], Emilio J. Compte [bd,be], Jennifer Corrigan [bf], Getrude Cosmas [bg], Richard G. Cowden [bh], Kamila Czepczor-Bernat [bi], Marcin Czub [an], Wanderson Roberto da Silva [bj], Mahboubeh Dadfar [bk], Simon E. Dalley [bl], Lionel Dany [ao], Jesus Alfonso D. Datu [bm], Pedro Henrique Berbert de Carvalho [bn,bo], Gabriel Lins de Holanda Coelho [bf], Avila Odia S. De Jesus [v], Sonia Harzallah Debbabi [bp], Sandesh Dhakal [bq], Francesca Di Bernardo [br], Donka D. Dimitrova [bs,bt], Jacinthe Dion [bu], Barnaby Dixson [bv], Stacey M. Donofrio [bl], Marius Drysch [bw], Hongfei Du [bx], Angel M. Dzhambov [bt,by], Claire El-Jor [bz], Violeta Enea [ca], Mehmet Eskin [cb], Farinaz Farbod [cc], Lorleen Farrugia [ar], Leonie Fian [c], Maryanne L. Fisher [cd], Michał Folwarczny [ce], David A. Frederick [cf], Matthew Fuller-Tyszkiewicz [ax], Adrian Furnham [cg], Antonio Alías García [ch], Shulamit Geller [ci], Marta Ghisi [at,cj], Alireza Ghorbani [ck], Maria Angeles Gomez Martinez [cl], Sarah Gradidge [a], Sylvie Graf [cm], Caterina Grano [aa], Gyöngyvér Gyene [cn], Souheil Hallit [co,cp], Motasem Hamdan [cq], Jonathan E. Handelzalts [ci,cr], PaulH.P. Hanel [cs], Steven R. Hawks [ct], Issa Hekmati [cu], Mai Helmy [cv,cw], Tetiana Hill [cx], Farah Hina [cy], Geraldine Holenweger [cz], Martina Hřebíčková [cm], Olasupo Augustine Ijabadeniyi [da], Asma Imam [cq], Başak İnce [db], Natalia Irrazabal [dc],

* Corresponding author. School of Psychology and Sport Science, Anglia Ruskin University, Cambridge, Cambridgeshire, CB1 1PT, United Kingdom
E-mail address: viren.swami@aru.ac.uk (V. Swami).

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Rasa Jankauskiene [y], Ding-Yu Jiang [dd], Micaela Jiménez-Borja [ah], Verónica Jiménez-Borja [de], Evan M. Johnson [cf], Veljko Jovanović [df], Marija Jović [dg], Marko Jović [dh], Alessandra Costa Pereira Junqueira [di,dj], Lisa-Marie Kahle [dk], Adam Kantanista [ai], Ahmet Karakiraz [dl], Ayşe Nur Karkin [cb], Erich Kasten [dm], Salam Khatib [dn], Nuannut Khieowan [do], Patricia Joseph Kimong [bg], Litza Kiropoulos [dp], Joshua Knittel [cz], Neena Kohli [dq], Mirjam Koprivnik [dr], Aituar Kospakov [ds,dt], Magdalena Król-Zielińska [ai], Isabel Krug [dp], Garry Kuan [du], Yee Cheng Kueh [dv], Omar Kujan [dw], Miljana Kukić [af], Sanjay Kumar [dx], Vipul Kumar [dy], Nishtha Lamba [dz], Mary Anne Lauri [ar], Maria Fernanda Laus [di,dj], Liza April LeBlanc [cd], Hyejoo J. Lee [ea], Małgorzata Lipowska [eb], Mariusz Lipowski [ec], Caterina Lombardo [aa], Andrea Lukács [ed], Christophe Maïano [i,ee], Sadia Malik [ef], Mandar Manjary [dx,eg], Lidia Márquez Baldó [eh], Martha Martinez-Banfi [ei,ej], Karlijn Massar [ek], Camilla Matera [el], Olivia McAnirlin [am], Moisés Roberto Mebarak [em], Anwar Mechri [en], Juliana Fernandes Filgueiras Meireles [eo], Norbert Mesko [ep], Jacqueline Mills [ax], Maya Miyairi [eq], Ritu Modi [dq], Adriana Modrzejewska [er], Justyna Modrzejewska [es], Kate E. Mulgrew [bv], Taryn A. Myers [et], Hikari Namatame [eu], Mohammad Zakaria Nassani [ev], Amanda Nerini [el], Félix Neto [ew], Joana Neto [ex], Angela Nogueira Neves [ey], Siu-Kuen Ng [ez], Devi Nithiya [fa], Jiaqing O [t], Sahar Obeid [fb], Camila Oda-Montecinos [fc], Peter Olamakinde Olapegba [w], Tosin Tunrayo Olonisakin [f], Salma Samir Omar [fd], Brynja Örlygsdóttir [ad], Emrah Özsoy [dl], Tobias Otterbring [fe], Sabine Pahl [c], Maria Serena Panasiti [aa,ff], Yonguk Park [fg], Muhammad Mainuddin Patwary [fh,fi], Tatiana Pethö [aj], Nadezhda Petrova [fj], Jakob Pietschnig [fk], Sadaf Pourmahmoud [g], Vishnunarayan Girishan Prabhu [fl], Vita Poštuvan [fm,fn], Pavol Prokop [fo,fp], Virginia L. Ramseyer Winter [fq], Magdalena Razmus [fr], Taotao Ru [ay,az], Mirjana Rupar [cm], Reza N. Sahlan [fs], Mohammad Salah Hassan [ft], Anđela Šalov [fu], Saphal Sapkota [fv], Jacob Owusu Sarfo [fw], Yoko Sawamiya [et], Katrin Schaefer [fx,fy], Michael Schulte-Mecklenbeck [cz,fz], Veya Seekis [ga], Kerim Selvi [gb], Mehdi Sharifi [gc], Anita Shrivastava [dz], Rumana Ferdousi Siddique [gd], Valdimar Sigurdsson [ge], Vineta Silkane [gf], Ana Šimunić [fu], Govind Singh [dq], Alena Slezáčková [gg], Christine Sundgot-Borgen [gh], Gill Ten Hoor [ek], Passagorn Tevichapong [gi], Arun Tipandjan [gj], Jennifer Todd [a,b], Constantinos Togas [m], Fernando Tonini [dc], Juan Camilo Tovar-Castro [gk], Lise Katrine Jepsen Trangsrud [al], Pankaj Tripathi [dq], Otilia Tudorel [gl], Tracy L. Tylka [gm], Anar Uyzbayeva [dt], Zahir Vally [gn], Edmunds Vanags [go], Luis Diego Vega [gp], Aitor Vicente-Arruebarrena [cl], Jose Vidal-Mollón [eh], Roosevelt Vilar [gq], Hyxia Villegas [gp], Mona Vintilă [gl], Christoph Wallner [bw], Simon Whitebridge [n], Sonja Windhager [fx,fy], Kah Yan Wong [gr], Eric Kenson Yau [gs], Yuko Yamamiya [gt], Victoria Wai Lan Yeung [gs,gu], Marcelo Callegari Zanetti [gv], Magdalena Zawisza [a], Nadine Zeeni [bz], Martina Zvaríková [fo], Stefan Stieger [gw]

[a] School of Psychology, Sport, and Sensory Sciences, Anglia Ruskin University, Cambridge, United Kingdom
[b] Centre for Psychological Medicine, Perdana University, Kuala Lumpur, Malaysia
[c] Department of Cognition, Emotion, and Methods in Psychology, Faculty of Psychology, University of Vienna, Vienna, Austria
[d] Institute of Psychology, University of Tartu, Tartu, Estonia
[e] Department of Psychology, Koç University, Istanbul, Turkiye
[f] Department of Psychology and Behavioural Studies, Ekiti State University, Ado-Ekiti, Nigeria
[g] Department of Art Studies, Tarbiat Modares University, Tehran, Iran
[h] Department of Psychology, University of Chittagong, Chattogram, Bangladesh
[i] Department of Psychoeducation and Psychology, Université Du Québec en Outaouais, Saint-Jérôme, Canada
[j] INSPECT-LB: National Institute of Public Health, Clinical Epidemiology, and Toxicology, Beirut, Lebanon
[k] School of Pharmacy, Lebanese International University, Beirut, Lebanon
[l] Department of Management, Ahmed Bin Mohammad Military College, Doha, Qatar
[m] Faculty of Psychology, Panteion University of Social and Political Sciences, Athens, Greece
[n] Royal College of Surgeons Ireland-Bahrain, Adliya, Bahrain
[o] Department of Midwifery, Faculty of Health Sciences, Munzur University, Tunceli, Turkiye
[p] Department of Oral Medicine and Diagnostic Sciences, Vision College of Dentistry and Nursing, Vision Colleges, Riyadh, Saudi Arabia
[q] Facultad de Ciencias de La Vida, Universidad Regional Amazónica Ikiam, Muyuna, Ecuador
[r] Federal Institute of Education, Science, and Technology of Southeast of Minas Gerais, Barbacena, Brazil
[s] Department of Psychology, Universitas Islam Indonesia, Yogyakarta, Indonesia
[t] Department of Psychology, Aberystwyth University, Ceredigion, United Kingdom

[u] Department of Psychology, Neapolis University Pafos, Paphos, Cyprus
[v] Department of Psychology, De La Salle University, Philippines
[w] Department of General Studies, The Polytechnic, Ibadan, Nigeria
[x] Department of Psychology, University of Ibadan, Ibadan, Nigeria
[y] Health Research and Innovation Science Centre, Faculty of Health Sciences, Klaipeda University, Klaipeda, Lithuania
[z] Department of Psychology, Faculty of Arts, Charles University, Prague, Czech Republic
[aa] Department of Psychology, Sapienza University of Rome, Rome, Italy
[ab] School of Social Sciences, Heriot-Watt University Malaysia, Putrajaya, Malaysia
[ac] School of Psychology, Faculty of Health, Liverpool John Moores University, Liverpool, United Kingdom
[ad] Faculty of Nursing and Midwifery, University of Iceland, Reykjavik, Iceland
[ae] Department of Nursing, Faculty of Health Sciences, Yalova, University, Yalova, Turkiye
[af] Department of Psychology, Faculty of Humanities and Social Sciences, University of Rijeka, Rijeka, Croatia
[ag] ÉCOBES-Research and Transfer, Cégep de Jonquière, Québec, Canada
[ah] Colegio de Ciencias Sociales y Humanidades, Universidad San Francisco de Quito USFQ, Quito, Ecuador
[ai] Department of Physical Education and Lifelong Sports, Poznań University of Physical Education, Poznań, Poland
[aj] Institute of Social Sciences of the Centre of Social and Psychological Sciences, Košice, Slovakia
[ak] Faculty of Humanities and Natural Sciences, Institute of Pedagogy, Andragogy, and Psychology, University of Prešov, Prešov, Slovakia
[al] Department of Sports, Physical Education and Outdoor Studies, University of South-Eastern Norway, Bø in Telemark, Norway
[am] Department of Parks, Recreation and Tourism Management, Clemson University, Clemson, SC, USA
[an] Institute of Psychology, University of Wrocław, Wrocław, Poland
[ao] Laboratory of Social Psychology, Aix-Marseille University, Aix-en-Provence, France
[ap] Department of Midwifery, Faculty of Health Sciences, Bartın University, Bartın, Turkiye
[aq] CentroSan Isidoro University Center, Seville, Spain
[ar] Department of Psychology, University of Malta, Msida, Malta
[as] Department of Cognitive Sciences, Psychology, Education, and Cultural Studies, University of Messina, Messina, Italy
[at] Department of General Psychology, University of Padova, Padova, Italy
[au] Department of Biomedical Sciences, University of Padova, Padova, Italy
[av] Faculty of Psychology, Chulalongkorn University, Bangkok, Thailand
[aw] Department of Psychology, Faculty of Liberal Arts, Thammasat University, Pathumthani, Thailand
[ax] School of Psychology, Deakin University, Geelong, Australia
[ay] Lab of Light and Physio-Psychological Health, National Center for International Research on Green Optoelectrics, South China Normal University, Guangzhou, China
[az] Guangdong Provincial Key Laboratory of Optical Information Materials and Technology & Institute of Electronic Paper Displays, South China Academy of Advanced Optoelectronics, South China Normal University, Guangzhou, China
[ba] Department of Psychology, Graduate School of Arts and Science, New York University, New York, USA
[bb] Department of Psychology, Soochow University, Taipei, Taiwan
[bc] Department of Educational Psychology and Guidance, Faculty of Education, Mahasarakham University, Maha Sarakham, Thailand
[bd] School of Psychology, Universidad Adolfo Ibáñez, Penalolen, Chile
[be] Comenzar de Nuevo Treatment Center, Monterrey, Mexico
[bf] School of Applied Psychology, University College Cork, Cork, Ireland
[bg] Faculty of Psychology and Education, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia
[bh] Human Flourishing Program, Harvard University, Cambridge, USA
[bi] Department of Pediatrics, Pediatric Obesity and Metabolic Bone Diseases, Faculty of Medical Sciences in Katowice, Medical University of Silesia, Katowice, Poland
[bj] Graduate Program in Food, Nutrition, and Food Engineering, São Paulo State University, São Paulo, Brazil
[bk] Department of Addiction, School of Behavioral Sciences and Mental Health (Tehran Institute of Psychiatry), Iran University of Medical Sciences, Tehran, Iran
[bl] Department of Psychology, University of Groningen, Groningen, the Netherlands
[bm] Academic Unit of Human Communication, Learning, and Development, Faculty of Education. The University of Hong Kong, China
[bn] Body Image and Eating Disorders Research Group, Federal University of Juiz de Fora, Juiz de Fora, Brazil
[bo] Institute of Psychiatry, University of São Paulo, São Paulo, Brazil
[bp] Faculty of Medicine, University of Sousse, Sousse, Tunisia
[bq] Central Department of Psychology, Tribhuvan University, Kathmandu, Nepal
[br] Department of Psychology, University of Campania Luigi Vanvitelli, Caserta, Italy
[bs] Department of Health Management and Healthcare Economics, Faculty of Public Health, Medical University of Plovdiv, Plovdiv, Bulgaria
[bt] Environmental Health Division, Research Institute at Medical University of Plovdiv, Medical University of Plovdiv, Plovdiv, Bulgaria
[bu] Department of Psychology, Université Du Québec à Trois-Rivières, Trois-Rivières, Canada
[bv] School of Health, University of the Sunshine Coast, Moreton Bay, Australia
[bw] Department of Plastic and Hand Surgery, BG University Hospital Bergmannsheil Bochum, Ruhr University Bochum, Bochum, Germany
[bx] Department of Psychology, Beijing Normal University at Zhuhai, Zhuhai, China
[by] Health and Quality of Life in a Green and Sustainable Environment Research Group, Strategic Research and Innovation Program, Medical University of Plovdiv, Plovdiv, Bulgaria
[bz] Department of Natural Sciences, School of Arts and Sciences, Lebanese American University, Beirut, Lebanon
[ca] Department of Psychology, Alexandru Ioan Cuza University, Iași, Romania
[cb] Department of Psychology, Koc University, Istanbul, Turkiye
[cc] Department of Textile and Fashion Design, Alzahra University, Tehran, Iran
[cd] Department of Psychology, Saint Mary's University, Halifax, Canada
[ce] Discipline of Marketing, J.E. Cairnes School of Business & Economics, University of Galway, Galway, Ireland
[cf] Crean College of Health and Behavioral Sciences, Chapman University, Orange, USA
[cg] Department of Leadership and Organizational Behaviour, Norwegian Business School, Oslo, Norway
[ch] Department of Education, University of Almería, Almería, Spain
[ci] School of Behavioral Sciences, The Academic College of Tel Aviv-Yaffo, Tel Aviv-Yafo, Israel
[cj] Unità Operativa Complessa (UOC) Hospital Psychology, Padova University Hospital, Padova, Italy
[ck] Department of Social Sciences, Payam Noor University, Tehran, Iran
[cl] Faculty of Psychology, Pontifical University of Salamanca, Salamanca, Spain
[cm] Institute of Psychology, Czech Academy of Sciences, Brno, Czech Republic
[cn] Doctoral School of Psychology, Eötvös Loránd University, Budapest, Hungary
[co] School of Medicine and Medical Sciences, Holy Spirit University of Kaslik, Jounieh, Lebanon
[cp] Applied Science Research Center, Applied Science Private University, Amman, Jordan
[cq] Faculty of Public Health, Al-Quds University, East Jerusalem, Palestine
[cr] Department of Psychiatry, University of Michigan, Ann Arbor, USA
[cs] Department of Psychology, University of Essex, Colchester, United Kingdom
[ct] Department of Kinesiology and Health Science, Utah State University, Logan, USA

[cu] Department of Psychology, Faculty of Human Science, University of Maragheh, Maragheh, Iran
[cv] Department of Psychology, College of Education, Sultan Qaboos University, Muscat, Oman
[cw] Department of Psychology, Faculty of Arts, Menoufia University, Shebin El Kom, Egypt
[cx] Hertfordshire Business School, University of Hertfordshire, Hatfield, United Kingdom
[cy] Department of Psychiatry, University of Cambridge, Cambridge, United Kingdom
[cz] Department of Consumer Behavior, University of Bern, Bern, Switzerland
[da] Department of Sociology and Social Justice, Afe Babalola University, Ado-Ekiti, Nigeria
[db] Centre for Research in Eating and Weight Disorders, Department of Psychological Medicine, Institute of Psychiatry, Psychology, and Neuroscience, King's College London, London, United Kingdom
[dc] Faculty of Social Sciences, University of Palermo, Buenos Aires, Argentina
[dd] Department of Psychology, National Chung Cheng University, Chia Yi, Taiwan
[de] Colegio de Comunicación y Artes Contemporáneas, Universidad San Francisco de Quito USFQ, Quito, Ecuador
[df] Department of Psychology, Faculty of Philosophy, University of Novi Sad, Novi Sad, Serbia
[dg] Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia
[dh] Faculty of Medicine, University of Belgrade, Belgrade, Serbia
[di] Department of Psychology, University of São Paulo, Ribeirão Preto, Brazil
[dj] Department of Nutrition, University of Ribeirão Preto, Ribeirão Preto, Brazil
[dk] Faculty of Life Sciences, Medical School Hamburg, Hamburg, Germany
[dl] Sakarya Business School, Sakarya University, Sakarya, Turkiye
[dm] Practice for Psychotherapy, Am Krautacker 25, Travemünde, Germany
[dn] Faculty of Health Professions, Al-Quds University, East Jerusalem, Palestine
[do] Asian Studies Department, Faculty of International Studies, Prince of Songkla University, Phuket Campus, Phuket, Thailand
[dp] School of Psychological Sciences, University of Melbourne, Melbourne, Australia
[dq] Department of Psychology, University of Allahabad, Prayagraj, India
[dr] Institute of Anton Martin Slomsek, Primary School Montessori, Maribor, Slovenia
[ds] Department of Sociology and Social Work, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[dt] Department of General Education Disciplines, Astana IT University, Astana, Kazakhstan
[du] Exercise and Sport Sciences Programme, School of Health Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia
[dv] Biostatistics and Research Methodology Unit, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia
[dw] Oral Diagnostics and Surgical Sciences, UWA Dental School, The University of Western Australia, Nedlands, Australia
[dx] Department of Psychology, D.A.V. College, Muzaffarnagar, India
[dy] Department of Psychology, Kashi Naresh Government Post-Graduate College, Gyanpur, India
[dz] Department of Psychology, Middlesex University Dubai, Dubai, United Arab Emirates
[ea] Department of Counselling Psychology and Social Welfare, Handong Global University, Pohang, South Korea
[eb] Institute of Psychology, University of Gdańsk, Gdańsk, Poland
[ec] Faculty of Social and Humanities, University WSB Merito, Gdansk, Poland
[ed] Faculty of Health Sciences, University of Miskolc, Miskolc, Hungary
[ee] Cyberpsychology Laboratory, Department of Psychoeducation and Psychology, Université Du Québec en Outaouais (UQO), Saint-Jérôme, Canada
[ef] Department of Psychology, University of Sargodha, Sargodha, Pakistan
[eg] M.M.D. Public School, Brahmpuri, Muzaffarnagar, India
[eh] Department of Research Methods and Diagnosis in Education, University of València, València, Spain
[ei] Faculty of Legal and Social Sciences, Simón Bolívar University, Barranquilla, Colombia
[ej] Life Science Research Centre, Simón Bolívar University, Barranquilla, Colombia
[ek] Department of Work and Social Psychology, Maastricht University, Maastricht, the Netherlands
[el] Department of Education, Languages, Intercultures, Literatures, and Psychology, University of Florence, Florence, Italy
[em] Department of Psychology, Universidad Del Norte, Barranquilla, Colombia
[en] Faculty of Medicine of Monastir, Eya Medical Centre, Monastir, Tunisia
[eo] Department of Family and Community Medicine, School of Community Medicine, University of Oklahoma, Tulsa, USA
[ep] Institute of Psychology, University of Pécs, Pécs, Hungary
[eq] Department of Health Sciences, DePaul University, Chicago, USA
[er] Department of Medical Anthropology, Faculty of Medical Sciences in Katowice, Medical University of Silesia, Katowice, Poland
[es] Institute of Pedagogy, University of Bielsko-Biala, Bielsko-Biala, Poland
[et] Department of Psychology, Virginia Wesleyan University, Virginia Beach, USA
[eu] Faculty of Human Sciences, University of Tsukuba, Tsukuba, Japan
[ev] Department of Restorative and Prosthetic Dental Sciences, College of Dentistry, Dar Al Uloom University, Riyadh, Saudi Arabia
[ew] Faculty of Psychology and Educational Sciences, University of Porto, Porto, Portugal
[ex] REMIT – Research on Economics, Management and Information Technologies, Universidade Portucalense, Porto, Portugal
[ey] Division of Research, Physical Education College of the Brazilian Army, Rio de Janeiro, Brazil
[ez] Physical Education Unit, Chinese University of Hong Kong, China
[fa] Department of Physiology, Mahatma Gandhi Medical College and Research Institute, Puducherry, India
[fb] Social and Education Sciences Department, School of Arts and Sciences, Lebanese American University, Jbeil, Lebanon
[fc] Institute of Social Sciences, Universidad de O'Higgins, Rancagua, Chile
[fd] Department of Dermatology, Venereology, and Andrology, Alexandria University, Alexandria, Egypt
[fe] Department of Management, University of Agder, Kristiansand, Norway
[ff] Santa Lucia Foundation, Scientific Institute for Research and Healthcare, Rome, Italy
[fg] Department of Psychology, Kyungnam University, Changwon, South Korea
[fh] Environment and Sustainability Research Initiative, Khulna, Bangladesh
[fi] Environmental Science Discipline, Life Science School, Khulna University, Khulna, Bangladesh
[fj] Department of Human Anatomy, Histology and Embryology, Faculty of Medicine, Medical University of Plovdiv, Plovdiv, Bulgaria
[fk] Department of Developmental and Educational Psychology, Faculty of Psychology, University of Vienna, Vienna, Austria
[fl] Industrial and Systems Engineering, University of North Carolina, Charlotte, USA
[fm] Slovene Centre for Suicide Research, Andrej Marusic Institute, University of Primorska, Koper, Slovenia
[fn] Department of Psychology FAMNIT, University of Primorska, Koper, Slovenia
[fo] Department of Environmental Ecology and Landscape Management, Faculty of Natural Sciences, Comenius University in Bratislava, Bratislava, Slovakia
[fp] Institute of Zoology, Slovak Academy of Sciences, Bratislava, Slovakia
[fq] School of Social Work, University of Missouri, Columbia, USA
[fr] Institute of Psychology, Marie Curie-Skłodowska University, Lublin, Poland
[fs] Department of Counseling, School, and Educational Psychology, Graduate School of Education, University at Buffalo-SUNY, Buffalo, USA
[ft] Management Department, College of Business Administration (COBA), A'Sharqiyah University (ASU), Ibra, Oman
[fu] Department of Psychology, University of Zadar, Zadar, Croatia

[fv] KOSHISH-National Mental Health Self-Help Organization, Kusunti, Lalitpur, Nepal
[fw] Department of Health, Physical Education and Recreation, University of Cape Coast, Cape Coast, Ghana
[fx] Department of Evolutionary Anthropology, University of Vienna, Vienna, Austria
[fy] Human Evolution and Archaeological Sciences, University of Vienna, Vienna, Austria
[fz] Max Planck Institute for Human Development, Berlin, Germany
[ga] School of Applied Psychology, Griffith University, Gold Coast, Australia
[gb] Department of Psychology, Eskişehir Osmangazi University, Eskişehir, Turkiye
[gc] Department of Psychology, Islamic Azad University, Bandar Gaz, Iran
[gd] Department of Psychology, University of Dhaka, Dhaka, Bangladesh
[ge] Department of Business Administration, Reykjavik University, Reykjavik, Iceland
[gf] Faculty of Social Sciences, Vidzeme University of Applied Sciences, Valmiera, Latvia
[gg] Department of Medical Psychology and Psychosomatics, Faculty of Medicine, Masaryk University, Brno, Czech Republic
[gh] Regional Department for Eating Disorders, Oslo University Hospital, Oslo, Norway
[gi] Department of Psychology, Faculty of Humanities, Chiang Mai University, Chiang Mai, Thailand
[gj] International Centre for Psychological Counselling and Social Research, Puducherry, India
[gk] Department of Psychology, University of the Andes, Bogotá, Colombia
[gl] Department of Psychology, West University of Timişoara, Timişoara, Romania
[gm] Department of Psychology, The Ohio State University, Columbus, USA
[gn] Department of Clinical Psychology, United Arab Emirates University, Al Ain, United Arab Emirates
[go] Faculty of Education, Psychology, and Art, University of Latvia, Rīga, Latvia
[gp] Vice-rectory for Teaching, Research, and Extension, Universida Latina de Costa Rica, San José, Costa Rica
[gq] Department of Psychology, Massey University, Auckland, New Zealand
[gr] School of Psychology, University of Nottingham Malaysia, Semenyih, Malaysia
[gs] Department of Psychology, Lingnan University, China
[gt] Department of Undergraduate Studies, Temple University, Japan Campus, Tokyo, Japan
[gu] Wofoo Joseph Lee Consulting and Counselling Psychology Research Centre, Lingnan University, China
[gv] Department of Physical Education, São Judas Tadeu University, São Paulo, Brazil
[gw] Department of Psychology and Psychodynamics, Karl Landsteiner University of Health Sciences, Krems an der Donau, Austria

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ABSTRACT

Detachment from nature is contributing to the environmental crisis and reversing this trend requires detailed monitoring and targeted interventions to reconnect people to nature. Most tools measuring nature exposure and attachment were developed in high-income countries and little is known about their robustness across national and linguistic groups. Therefore, we used data from the Body Image in Nature Survey to assess measurement invariance of the Nature Exposure Scale (NES) and the Connectedness to Nature Scale (CNS) across 65 nations, 40 languages, gender identities, and age groups (N = 56,968). While multi-group confirmatory factor analysis (MG-CFA) of the NES supported full scalar invariance across gender identities and age groups, only partial scalar invariance was supported across national and linguistic groups. MG-CFA of the CNS also supported full scalar invariance across gender identities and age groups, but only partial scalar invariance of a 7-item version of the CNS across national and linguistic groups. Nation-level associations between NES and CNS scores were negligible, likely reflecting a lack of conceptual clarity over what the NES is measuring. Individual-level associations between both measures and sociodemographic variables were weak. Findings suggest that the CNS-7 may be a useful tool to measure nature connectedness globally, but measures other than the NES may be needed to capture nature exposure cross-culturally.

1. Introduction

At the turn of the century, the United Nations Millennium Declaration recognised that insufficient respect for nature is a fundamental challenge for international relations and global sustainable development (United Nations General Assembly, 2000). Despite ongoing efforts, anthropogenic-related climate change, biodiversity loss, and land, water, and air pollution are accelerating (e.g., Goudie, 2019). Some observers have suggested that this is, at least in part, a consequence of a growing detachment from the natural world, especially among increasingly urbanised populations (Beery et al., 2023; Soga & Gaston, 2016). Reversing these trends requires an understanding of the drivers and barriers of ecological and pro-environmental behaviours, and using this knowledge to promote widespread behaviour change (Grilli & Curtis, 2021; Schultz & Kaiser, 2012).

One important avenue of research concerns people's physical contact with, and psychological connectedness to, the natural world. In terms of the former, the relationship between recreational nature exposure (e.g., leisure visits to parks, woodlands, and beaches) and a range of public and private pro-environmental behaviours has been shown to be consistently positive (De Ville et al., 2021; Martin et al., 2020). Regarding psychological connectedness, robust evidence shows that people who feel more connected to the natural world – independent of their actual exposure – have more positive attitudes towards the natural environment, ecological behaviours, and nature protection (for meta-analyses, see Barragan-Jason et al., 2022; Whitburn et al., 2020). They also exhibit better well-being and mental health (Capaldi et al., 2014; White et al., 2021).

The mechanisms underpinning these relationships are thought to reflect a combination of genetic inheritance (Kellert & Wilson, 1993), personal experience and associative learning (e.g., Yannick & de Block, 2011), and salient sociocultural norms (Bourassa, 1990). In addition, nature exposure and nature connectedness are likely to be mutually reinforcing. Positive contact with the natural world can increase feelings of connectedness to nature (e.g., Fränkel et al., 2019; Lengieza & Swim, 2021; Martin et al., 2020; Swami, Barron, et al., 2020), with a meta-analysis of experimental manipulations and field interventions reporting a moderate positive mean effect of nature contact on nature connectedness (g = .44, 95% CI = .31, .58; Sheffield et al., 2022). Conversely, greater nature connectedness can encourage people to seek more nature exposure (Martin et al., 2020; Stehl et al., 2024). Positive experiences may then strengthen nature connectedness over time.

Although improving our understanding of these processes remains important, our objective here was to consider how physical contact and psychological connectedness with nature are measured and, in particular, how generalisable existing measures are across linguistic and national contexts. Given that the environmental crisis is a global phenomenon (Goudie, 2019), adequate measurement and monitoring across contexts requires instruments that can be deployed reliably in multiple settings to make robust comparisons. Crucial to this issue is the concept of *measurement invariance*, the notion that a measurement tool should measure the same underlying construct in the same way across different groups (Swami & Barron, 2019; Vandenberg & Lance, 2000), which in turn ensures that measurement biases leading to artefactual, inaccurate, or irreplicable results are avoided (Fischer et al., 2023). Measurement invariance can be determined at different levels, with scalar or partial scalar invariance typically considered a minimum threshold for comparison of latent means (Chen, 2007).

To date, however, determining measurement invariance of key nature exposure and nature connectedness instruments has been hampered because most research – including the development of instruments to measure these constructs – has been conducted in a small handful of countries in the Global North (Tirri et al., 2021; Zhang et al., 2020). Here, we aimed to address this shortcoming. Specifically, using data from 65 countries, we aimed to explore the measurement invariance of two well-known instruments across multiple linguistic and national contexts. The first was a measure of nature exposure – the Nature Exposure Scale (NES; Kamitsis & Francis, 2013) – while the second was a measure of nature connectedness, the Connectedness to Nature Scale (CNS; Mayer & Frantz, 2004). We briefly review what is currently known about these instruments.

1.1. Nature exposure

Many definitions of nature exposure, or nature contact, exist (Holland et al., 2021). Much of the research linking nature exposure to health and well-being uses remote sensing data to estimate the percentage of vegetation around the home using various radial buffers (e.g., Browning & Lee, 2017) or distance to local green and blue spaces (e.g., Geary et al., 2023). Others consider vegetation around other core locations, such as work/school (e.g., Dadvand et al., 2015), or explore more deliberative, intentional nature contact, such as leisure visits to natural settings (e.g., Garrett et al., 2023). Finally, many of the beneficial effects of nature contact on health and pro-environmentalism may depend on psychological awareness of exposure, or a certain degree of mindfulness of this contact with nature (e.g., Macaulay et al., 2022; Richardson, Hamlin, Butler, et al., 2022).

One self-report measure that attempts to address all three aspects – that is, everyday nature around the home/work, recreational visits, and nature awareness – is the 4-item Nature Exposure Scale (NES, Kamitsis & Francis, 2013; see Appendix 1 for items). Although the instrument has been utilised in diverse national groups (e.g., Arroz et al., 2022; Baceviciene et al., 2021; Picanço et al., 2024; Stieger et al., 2022), its factorial validity has been infrequently assessed. Studies with adults from the United States (Swami et al., 2016), Portugal (Arroz et al., 2022; Picanço et al., 2024), and Lithuania (Matukyniene et al., 2021) suggest scores are unidimensional, whereas a study with an online sample (nationality unreported) found that it was necessary to drop one item (Item #1) to achieve unidimensionality (Wood et al., 2019).

The equivocal nature of findings *vis-à-vis* the factorial validity of the NES may reflect the fact that a single instrument is trying to measure very different types of exposure using different response outcomes. Thus, while some authors have suggested that overall scores on the 4-item NES demonstrate adequate indices of face validity (e.g., Picanço et al., 2024; Swami et al., 2019), others have implied that it is only the two items that assess direct contact with nature that truly assesses nature exposure (Goh et al., 2023). As scholars increasingly seek brief self-report measures of nature exposure, a fuller understanding of the factorial validity of the NES, including item behaviour, is vital (Swami, 2024). In the same vein, more can be done to understand the psychometric properties of this instrument beyond singular national groups, including in terms of gendered identities, age groups, and languages. This is particularly important as some work has suggested that demographic factors affect responding on the NES (Picanço et al., 2024).

1.2. Connectedness to nature

Although many measures of nature connectedness exist (Martin & Czellar, 2016; Richardson et al., 2019), one of the most widely used is the Connectedness to Nature Scale (CNS; Mayer & Frantz, 2004; cited more than 3500 times based on Google Scholar citations up to August 2024). In the original study reporting on the development of the 14-item CNS (see Appendix 1 for items), Mayer and Frantz (2004) reported – based on exploratory factor analyses (EFAs) – that scores were unidimensional in two community and three college samples from the United States. The unidimensional model of the 14-item CNS scores has also been supported in other national and linguistic contexts, such as Brazil (Pessoa et al., 2016), China (Li & Wu, 2016), Italy (Lovati et al., 2023), and Spain (Mattas-Terrón & Elósegui-Bandera, 2012).

However, not all studies have demonstrated adequate fit of the unidimensional model of CNS scores, and in some national contexts, a unidimensional model was only supported once several items were eliminated: one item in Spain (Olivos et al., 2013), three items in France (Navarro et al., 2017) and Australia (Pearce et al., 2022), four each in Kenya (Marczak & Sorokowski, 2018) and South Korea (Gim et al., 2019), and seven items in Poland (Strzelecka et al., 2023). Likewise, Anđić and Šuperina (2021) reported difficulties translating four CNS items into Croatian, resulting in a 10-item, single factor, instrument. In Turkey, the CNS reduced to two dimensions reflecting integration with nature (two items) and feeling part of nature (six items; Bektaş et al., 2017).

These equivocal findings may reflect the fact items on the CNS contain two verbal structures: items that include the word "feel" as an emotional component and other items that more closely reflect a cognitive belief in one's connection to nature (Lee & Oh, 2021; Perrin & Benassi, 2009). Alternatively, it is possible that some CNS items either function poorly or are redundant in some national contexts. Based on Item Response Theory, Pasca et al. (2017) suggested that seven CNS items (Items #1, 3, 4, 8, 12, 13, and 14) were either redundant or lacked adequate fit in a sample of Spanish adults. In subsequent analyses, the same authors also suggested that a truncated, 7-item version of the CNS (i.e., the CNS-7) had adequate composite reliability, although factorial validity was not assessed. In a more recent study with Brazilian university students, Rosa et al. (2022) reported that scores on the CNS-7 were unidimensional and that the CNS-7 had slightly improved fit indices compared to the full version.

To date, however, assessments of the measurement invariance of the CNS across national groups in the same study, conducted at the same time, remain rare. One study using samples from seven nations (Spain, the Netherlands, Turkey, Portugal, Germany, France, and Hungary) utilising the CNS-7 supported metric, but not scalar invariance, once the loading associated with Item #7 was relaxed (Navarro et al., 2022). In terms of the 14-item CNS, Pasca et al. (2018) examined measurement invariance across samples from Spain and the United States (the latter representing data from Mayer & Frantz, 2004). Their analyses indicated support for configural, but not metric, invariance. Based on Item Response Theory, Pasca et al. (2018) further noted that seven of the CNS items showed differential functioning across groups. These studies suggest that the latent connectedness to nature construct is not equivalent across national groups (Navarro et al., 2022).

Beyond invariance across national groups, very little work has assessed invariance of the CNS across other sociodemographic characteristics. For instance, only two studies have examined the measurement invariance of the CNS across gender identities. In samples of Italian adults, Di Fabio and Rosen (2019) and Lovati et al. (2023), respectively, reported that the CNS achieved full scalar invariance across women and men. However, it remains possible that gendered experiences – particularly across national or cultural groups – shape one's understanding and manifestations of connectedness to nature. Drawing on gender socialisation theories, for instance, McCright (2010) suggested that women, more so than men, are expected to demonstrate an ethic of care for the natural environment and exhibit both greater environmental concern (e.g., Xiao & McCright, 2015) and dispositional empathy with nature (Tam, 2013).

As such, there is a need to more carefully and comprehensively assess the extent to which the CNS is invariant across gender identities in multiple cultural contexts. Likewise, we are unaware of any previous work that has examined invariance of the CNS across age groups. Existing studies have reported equivocal results in terms of the association between CNS scores and age, with some studies reporting that CNS scores increase with older age (Swami et al., 2016) and other studies reporting no significant association (e.g., Swami et al., 2016). Other work has suggested that connectedness to nature dips in adolescence before returning to pre-adolescent levels in early adulthood (Richardson et al., 2019), where it then remains relatively stable (Anderson & Krettenauer, 2021). More work is needed to explore these patterns across different cultural contexts.

1.3. The present study

Large, multinational studies offer the best opportunity to deal with many of the issues noted above, particularly given that research on nature exposure and connectedness to nature often centres the experiences of respondents in the Global North (Barragan-Jason et al., 2023; Soga & Gaston, 2023). Thus, in the present study, we utilised data from the Body Image in Nature Survey (BINS; Swami, Tran et al., 2022), a collaborative, 253 researcher-crowdsourced project that gathered CNS and NES data between 2020 and 2022 from participants in 65 nations across 40 language groups with variance across gender identities and age groups. In terms of the NES, we considered whether a unidimensional model with all four items, as well as multidimensional models, would offer optimal fit. Given that there are few assessments of the factorial validity of this instrument and the limits of cross-sectional data for establishing the dimensionality of measures, we do not advance any specific hypotheses here. In terms of the CNS, we adopted an exploratory framework, considering the extent to which either the full 14-item CNS, or the truncated CNS-7, would balance item retention and measurement invariance across groups. As a preliminary hypothesis, we expected that the CNS-7 would demonstrate superior fit compared to the full CNS and would also evidence scalar or partial scalar invariance across groups.

A second objective was to assess whether, and the extent to which, nature exposure is significantly associated with connectedness to nature across nations. Our expectation, based on previous work, was of a small, positive correlation in the $r \sim .30$ range (Sheffield et al., 2022; Swami et al., 2016; Swami, Barron, et al., 2020). Finally, we also assessed the extent to which sociodemographic variables included in the BINS (i.e., financial security, urbanicity, educational qualifications, marital status, and racialised status) were associated with both nature exposure and connectedness to nature. Although this aspect of our study was more exploratory, based on the available evidence, we expected that greater nature exposure and connectedness to nature would be significantly associated with greater financial security, rural residence (e.g., Carrus et al., 2020; Richardson et al., 2019), higher educational qualifications (e.g., Nesbitt et al., 2019), being married/in a committed relationship (Pasanen et al., 2023), and racialised majority status (e.g., Murdock, 2019).

2. Materials and methods

2.1. Overview of the Body Image in Nature Survey

Full details of the Body Image in Nature Survey (BINS) are published elsewhere (Swami, Tran et al., 2022). Data were collected between November 2020 and February 2022 with community sampling, with the majority of recruitment taking place online. The overall project received ethics approval from the School Research Ethics Panel at the first author's institution (approval code: PSY-S19-015) and, unless exempt by national laws, all collaborating teams additionally obtained ethics approval from local institutional ethics committees or review boards. A list of nations, associated sample sizes, data collection methods, ethics approvals, and survey languages is presented in Supplementary Table S1. Sample sizes ranged from 204 in the United Arab Emirates (Arabic) to 3275 in Thailand.

2.2. Participants

The BINS dataset consists of 56,968 respondents, of whom 58.9% were women, 40.5% were men, and 0.6% reported another gender identity. Ages ranged from 18 to 99 years ($M = 33.10$, $SD = 13.79$). In terms of financial security compared to others of their age in their country, 25.5% and 49.6% felt more or equally secure, respectively, with 24.9% feeling less secure. Most (84.5%) lived in an urban rather than a rural (15.5%) area, and the majority reported at least completing secondary education (72.6%). In total, 53.0% were in a committed relationship including marriage. The majority (74.2%) self-identified as being part of a racialised majority in their country, whereas 11.3% identified as part of a racialised minority group (13.5% were uncertain and race data were not collected in France due to prohibition of the collection and storage of race-related data). Table 1 presents detailed sample description data for all individual nations. In six countries, data was collected in either two (Canada, Iceland, India, the Philippines, the United Arab Emirates [UAE]) or three (China) languages.

2.3. Measures

2.3.1. Nature exposure

The 4-item self-reported Nature Exposure Scale (NES; Kamitsis & Francis, 2013) covers perceptions about everyday nature exposure, frequency of more distal visits ("nature exposure"; Items #1 and #3), and attention paid to nature in both settings ("noticing nature"; Items #2 and #4; see Appendix 1 for English wording). Response anchors varied depending on the item, but all used 5-point scales. The NES was translated for use in the present project using the back-translation procedure (Brislin, 1986; for further information, see Swami, Tran et al., 2022) unless it was presented in English or a validated, localised version was available for use. A list of the 40 languages in which the BINS survey package was presented is reported in Supplementary Table S1 and all translations are available from the first author.

2.3.2. Connectedness to nature

The 14-item Connectedness to Nature Scale (CNS; Mayer & Frantz, 2004; items in English are presented in Appendix 1) uses a 5-point response scale: 1 (*strongly disagree*) to 5 (*strongly agree*). Unless presented in English, or where a previously validated translation was not available, the CNS was also translated for use in the BINS using the parallel back-translation procedure (see Supplementary Table S1).

2.3.3. Urbanicity

To assess urbanicity, participants were asked about their current place of residence, with response options adapted from Pedersen and Mortensen (2001) as follows: *capital city*, *capital city suburbs*, *provincial city (more than 100,000 residents)*, *provincial town (more than 10,000 residents)*, and *rural areas*. Response options were assigned values 1 to 5 (in the above order) for statistical analysis and collapsed into *urban* versus *rural* for descriptive purposes. This measure of urbanicity has been used in previous cross-national work (Swami et al., 2020).

2.3.4. Financial security

Following previous cross-national work (Swami et al., 2012, 2020), participants were asked to self-report how financially secure they felt

Table 1
Sample Descriptions of Data from the Body Image in Nature Survey (BINS).

Nation	Sample size	Mean age (*SD*)	% Women	Mean financial security (*SD*)	%Urban residence	%Secondary/tertiary education	%In committed relationship or married	%Racialised minority
Argentina	670	35.36 (13.6)	57	2.13 (.7)	98	81	50	9
Australia	1038	35.23 (13.1)	71	1.90 (.8)	93	77	55	18
Austria	1279	41.99 (16.5)	54	2.08 (.7)	67	62	63	9
Bahrain	441	30.47 (9.8)	74	1.98 (.6)	98	87	51	8
Bangladesh	460	29.30 (8.6)	42	1.78 (.8)	88	80	51	13
Bosnia & Herzegovina	406	43.93 (10.9)	64	2.15 (.7)	87	90	70	16
Brazil	1462	36.77 (12.0)	58	2.21 (.7)	99	86	66	12
Bulgaria	248	33.52 (14.1)	62	2.16 (.6)	92	54	52	4
Canada (English)	336	24.61 (10.0)	83	2.10 (.7)	82	36	48	14
Canada (French)	806	38.22 (12.8)	88	2.29 (.7)	78	95	72	7
Chile	422	36.14 (13.6)	79	2.28 (.8)	94	73	41	8
China (Cantonese)	409	20.50 (5.9)	58	2.18 (.7)	100	96	2	2
China (English)	349	21.93 (5.3)	65	1.79 (.7)	97	62	26	6
China (Mandarin)	1231	35.00 (7.3)	69	1.82 (.6)	95	92	86	4
Colombia	793	27.15 (11.5)	60	2.01 (.8)	96	57	22	7
Croatia	898	39.10 (12.1)	59	2.08 (.7)	71	91	69	2
Cyprus	363	34.31 (9.6)	65	2.09 (.7)	87	69	64	4
Czechia	700	38.10 (17.0)	66	2.29 (.6)	82	75	62	2
Ecuador	863	30.97 (12.3)	53	1.81 (.8)	86	65	33	11
Egypt	1627	23.62 (8.7)	72	2.06 (.6)	98	86	27	6
Estonia	449	38.93 (14.1)	63	2.10 (.7)	80	64	58	2
France	562	36.01 (14.2)	76	2.08 (.7)	64	67	47	NA
Germany	620	31.01 (11.9)	62	2.18 (.8)	83	64	58	12
Ghana	434	21.97 (4.5)	41	2.08 (.8)	84	72	32	26
Greece	556	31.49 (11.8)	65	2.03 (.7)	91	63	55	5
Hungary	654	32.80 (13.4)	69	2.07 (.6)	72	69	63	2
Iceland (English)	1149	38.50 (17.5)	50	2.27 (.7)	92	61	65	11
Iceland (Icelandic)	432	54.91 (15.5)	54	2.05 (.6)	75	81	78	3
India (Hindi)	1664	32.07 (11.8)	45	2.14 (.8)	73	78	45	13
India (Tamil)	376	36.78 (12.1)	52	1.71 (.6)	57	65	70	37
Indonesia	292	19.79 (3.2)	72	1.76 (.5)	87	43	14	3
Iran	1318	33.46 (11.3)	60	1.99 (.6)	95	82	61	29
Iraq	405	34.13 (12.1)	33	1.49 (.5)	100	97	45	53
Ireland	351	33.73 (12.4)	50	2.11 (.8)	76	80	62	5
Israel	493	30.77 (11.6)	62	2.13 (.7)	87	67	32	7
Italy	2307	33.17 (14.0)	62	1.95 (.6)	81	67	61	6

(*continued on next page*)

Table 1 (*continued*)

Nation	Sample size	Mean age (*SD*)	% Women	Mean financial security (*SD*)	%Urban residence	%Secondary/tertiary education	%In committed relationship or married	%Racialised minority
Japan	360	49.44 (16.6)	100	1.79 (.6)	90	81	61	8
Kazakhstan	380	30.07 (11.3)	53	2.04 (.6)	94	76	48	11
Latvia	827	41.04 (12.8)	66	2.02 (.7)	74	82	69	4
Lebanon	1295	25.74 (12.3)	67	1.93 (.7)	70	63	33	16
Lithuania	491	40.34 (12.8)	51	2.05 (.6)	72	84	74	3
Malaysia	1193	27.81 (8.7)	69	1.74 (.6)	76	84	29	30
Malta	347	35.52 (15.4)	72	2.10 (.7)	78	71	60	7
Nepal	353	25.78 (6.0)	50	1.77 (.7)	82	98	28	5
Netherlands	1004	46.81 (16.3)	53	2.05 (.6)	61	98	69	9
Nigeria	1274	31.64 (9.2)	34	1.85 (.8)	93	64	63	14
Norway	360	41.24 (11.6)	77	2.17 (.7)	78	92	77	4
Pakistan	267	20.59 (2.7)	28	2.16 (.9)	100	47	83	49
Palestine	401	27.64 (9.5)	25	2.01 (.6)	81	90	42	7
Philippines (English)	350	24.87 (11.2)	0	2.03 (.7)	97	56	24	13
Philippines (Tagalog)	504	37.43 (11.9)	73	1.83 (.7)	97	89	65	16
Poland	1954	30.51 (11.9)	62	1.99 (.7)	74	63	56	3
Portugal	363	36.53 (17.9)	68	2.05 (.7)	85	81	37	5
Romania	1819	26.94 (10.8)	53	2.05 (.7)	80	49	60	5
Russia	206	39.94 (11.8)	71	1.84 (.5)	97	84	67	8
Saudi Arabia	380	28.02 (9.7)	55	2.03 (.7)	94	83	33	20
Serbia	650	30.72 (11.3)	56	2.20 (.7)	95	65	65	10
Slovakia	814	37.79 (14.7)	54	1.92 (.6)	65	75	67	4
Slovenia	452	36.84 (14.9)	59	2.16 (.7)	49	87	66	2
South Africa	318	35.15 (16.1)	53	1.74 (.8)	78	73	45	31
South Korea	381	27.60 (9.7)	48	1.89 (.6)	98	54	43	52
Spain	1266	34.54 (16.3)	52	2.17 (.8)	88	82	43	5
Switzerland	377	46.48 (15.2)	52	1.98 (.7)	62	51	66	5
Taiwan	529	41.36 (13.6)	60	2.48 (.7)	90	92	67	7
Thailand	3275	25.85 (10.8)	62	1.76 (.6)	87	45	23	6
Tunisia	374	41.62 (15.2)	55	2.10 (.6)	96	90	63	0
Türkiye	2518	31.63 (11.5)	57	1.98 (.8)	97	61	57	14
Ukraine	141	39.00 (11.7)	59	1.74 (.6)	95	87	71	9
United Arab Emirates (Arabic)	204	26.37 (6.7)	73	2.07 (.4)	99	35	39	10
United Arab Emirates (English)	904	27.50 (11.8)	36	2.13 (.8)	98	73	43	31
United Kingdom	1243	37.99 (13.9)	54	2.03 (.7)	84	87	68	23
United States of America	2531	35.35 (12.7)	62	1.93 (.7)	85	82	61	20

Note. SD = standard deviation.

relative to others of their own age in their country of residence (1 = *less secure*, 2 = *same*, 3 = *more secure*).

2.3.5. Demographics

Highest educational qualification was assessed as follows: 1 = *no formal education*, 2 = *primary education*, 3 = *secondary education*, 4 = *still in full-time education*, 5 = *undergraduate degree*, 6 = *postgraduate degree*, 7 = *other*; marital status was assessed as: 1 = *single*, 2 = *single but in a committed relationship*, 3 = *married*, 4 = *other*; and racialised status relative to their country of residence was assessed as: 1 = *ethnic/racial majority*, 2 = *ethnic/racial minority*, 3 = *not sure*. The latter item provides a common metric of categorising ethnicity/race across diverse nations (Swami, Barron, et al., 2020). For descriptive purposes at the national level and for analyses, response options for highest educational qualification were collapsed into *secondary/tertiary* (secondary education, undergraduate degree, postgraduate degree) versus *other* (all remaining categories) and response options of racialised status were collapsed into *racialised minority* (racial minority) versus *other* (all remaining categories).

2.4. Procedures, ethics, and data sharing

Full procedural information about the BINS is provided in Swami et al. (2022). The BINS project was conducted in accordance with the principles of the Declaration of Helsinki and following all local institutional guidelines. In brief, once local ethics approval had been obtained or collaborators confirmed that approval was not required as per national laws (see Supplementary Table S1), researchers recruited participants from the community in their respective nations between November 2020 and February 2022. Inclusion criteria were being ≥ 18 years of age, a resident and citizen of the particular nation in which recruitment took place, and being able to complete a survey in the language in which it was presented. In all but nine locales (see Supplementary Table S1), data collection was conducted online. All participants were presented with a standardised information sheet and provided (digital or written) informed consent before completing an anonymous version of the BINS package. Upon completion, participants received debriefing information, which included contact information for the first author as well as a local researcher. The BINS data and our analytic codes are available on the Open Science Framework at https://osf.io/rfhwe/?view_only=dc87d4d3088b4f62922177fbbe06e8b6.

2.5. Analytic strategy

The general analytic plan, including structural and measurement invariance analyses of the key variables of the BINS (including the NES and CNS) is described in the BINS study protocol (Swami et al., 2022). Further analyses not covered in the study protocol were not preregistered separately.

The analysis proceeded in four steps, in a similar fashion for both the NES and CNS: first, CFA models were fitted to the total sample to determine the structure of the NES and test both the full CNS (henceforth "CNS-14") and the CNS-7 for unidimensionality. For the NES, unidimensional and 2-factor models were fitted, testing for the possible scale multidimensionality (nature exposure in everyday life and environments: Items #1 and #2; nature exposure outside everyday environments: Items #3 and #4). As the items further allude to a conditional structure (with Items #1 and #3 assessing levels of "nature exposure" in each domain and Items #2 and #4 assessing "noticing nature" in each domain), a unidimensional model with correlated error variances between Items #1 and #2, and Items #3 and #4, respectively was also fitted on the data (an analogous 2-factor model could not be tested, as it was under-identified with only 4 items). The best-fitting model was then used for further analysis. In the unidimensional model of the CNS, error variances of Items #5 and #7, and Items #5 and #10 were allowed to correlate (following Rosa et al., 2022). We expected a better model fit for the CNS-7 than the CNS-14, but followed this strategy to determine which version of the instrument should be used in further analysis.

Second, in the six countries where data was collected in multiple languages, measurement invariance of the NES and CNS was tested with multi-group CFAs (MG-CFAs) for cross-language survey presentation. Data from the same nations were merged in the subsequent measurement invariance analysis of nations only if scalar measurement invariance held within nations (i.e., all linguistic versions of the scales showed satisfactory invariance). This was only true for China. Where this was not the case, data for the two different language versions of the survey were kept separate in further analysis (i.e., Canada, Iceland, India, the Philippines, and the UAE). We therefore use the term "national groups" rather than "countries" where we are reporting results that include multiple languages within countries.

Third, measurement invariance of the CNS and NES was tested with MG-CFAs for: national groups, languages, gender identities (women vs. men vs. other gender identities), and age groups based on Arnett (2000) and Erikson (1968), namely young adulthood (18–24 years), middle adulthood (25–44 years) and older adulthood (≥ 45 years). Note that testing measurement invariance of languages implied mixing different national groups with the same language in analysis (e.g., English was the survey language in the UK, the USA, but, *inter alia*, also in one of the Chinese samples). Assuming scalar or at least partial scalar measurement invariance, we then examined latent means in these groups and, assuming at least metric invariance, we examined associations between the NES and CNS across national groups, using factor scores.

Fourth, assuming scalar or at least partial scalar measurement invariance, sociodemographic correlates of the NES and CNS factor scores were investigated with multilevel models (MLMs) across national groups. Predictors were financial security, urbanicity (urban vs. rural), education (secondary/tertiary vs. other), marital status (committed/married vs. other), and racialised identity (racialised minority vs. other).

Mplus 8.8 (Muthén & Muthén, 2022) was used for the CFAs, MG-CFAs, and MLMs. Significance was set to $p < .05$. For the structural analyses, the weighted mean- and variance-adjusted weighted least squares estimator (WLSMV) was used to account for the ordered-categorical item response formats of the NES and CNS. WLSMV estimates one loading parameter for each item, but #response options – 1 threshold parameters (one for each transition of one response option to the next) instead of a single intercept parameter per item. To account for missing data (0.4% in the NES, 1.4% in the CNS-14), full information maximum likelihood was used.

Measurement invariance analyses tested for configural invariance (i.e., same loading patterns across groups), metric invariance (i.e., same unstandardised loadings across groups), and scalar invariance (i.e., same unstandardised loadings and threshold parameters across groups). Based on the configural invariance models, reliability estimates (ω total) are presented for all groups. If full scalar measurement invariance could not be assumed, we aimed for partial scalar measurement invariance instead (i.e., equal item parameters across some groups and items, but not all). For this, the alignment method (e.g., Asparouhov & Muthén, 2023) was used for guidance. Alignment does not require exact measurement invariance, but instead seeks a solution that minimises the differences in loadings and threshold parameters across groups, while still retaining identical fit to the configural invariance model. The method provides for each item parameter information on the groups for which invariance holds and an R^2 measure that indicates the amount of invariance (typically, the more invariant, the higher the R^2; however, in some special cases, R^2 is a poor measure of invariance; Asparouhov & Muthén, 2023). This information was used to (a) select two items per scale (anchor items) for which invariance was assumed (two anchor items being sufficient for the comparison of latent means; Pokropek et al., 2019) and to (b) exclude groups that violated invariance the most. Additionally, we looked at the reliability of the scales in each group and the contributions of each group to the overall χ^2 values of the MG-CFAs. If composite reliabilities were low and/or the contributions to the χ^2 value were high, compared to sample size, groups were excluded from the final partial scalar measurement models.

For the assessment of model fit, commonly used fit indices were consulted: the comparative fit index (CFI; good/acceptable fit: $\gtrsim$ .95/.90), the Tucker-Lewis index (TLI; $\gtrsim$ .95/.90), the root-mean square error of approximation (RMSEA; good fit: $\lesssim$ .06) and its 90% confidence interval, and the standardised root mean square residual (SRMR; good fit $\lesssim$ .08; Hu & Bentler, 1999). The cut-off for the RMSEA was set to .15 for MG-CFAs with more than 10 groups (Rutkowski & Svetina, 2014). For the measurement invariance analyses, we present ΔCFI and ΔRMSEA values, and $\Delta\chi^2$ tests, but primarily interpreted the former two as they were not affected by sample size. For the comparison of metric to configural, and scalar to metric invariance models, the cut-offs ΔCFI $\lesssim$ .020/.010 and ΔRMSEA $\lesssim$ .030/.015 were used to indicate good fit of the respective stricter model (Rutkowski & Svetina, 2014).

For the MLMs, Bayesian estimation (using diffuse priors as specified in Mplus default settings) was used. This allowed obtaining correctly standardised (cf. van Assen et al., 2022) parameter estimates that were interpreted as measures of effect size (comparable to Pearson's *r*). For the dichotomous predictors, these estimates were further transformed into the metric of Cohen's *d* as well. The predictors of financial security, urbanicity, education, marital status, and racialised identity were groupmean-centred on Level 1, and their cluster-level means were further used as Level-2 predictors. Thereby, associations on the individual level (Level 1) and on the cluster-level (national groups; Level 2) could be optimally distinguished. However, to avoid overfitting on Level 2, we only kept significant Level-2 predictors in the final models.

3. Results

3.1. Nature exposure scale

3.1.1. Structural analysis in the total sample

The unidimensional model had poor to borderline fit to the data, judging by its CFI value (and disregarding TLI and RMSEA values, because of the small degrees of freedom of this model; Table 2). Items #1 and #3 had lower standardised loadings (.54 and .67) than Items #2 and #4 (.84 and .72; all *ps* < .001). Including correlated errors between Items #1 and #2, and #3 and #4, respectively, to accommodate the model for their conditional structure improved the model fit considerably (to keep this model identified, the strength of the residual association between the two items needed to be constrained to equality across pairs). The standardised items loadings in this model were .44, .86, .60, and .67, with residual correlations between Items #1 and #2, and #3 and #4, of .35 and .27 (all *ps* < .001).

In contrast, a correlated 2-factor model (setting equality constraints for the similar loadings in each pair of Items #1 and #3, and #2 and #4 to obtain admissible parameter estimates of the residual variances) resulted in a poorer model fit (Table 2). In this model, Items #1 and #2 loaded on one factor (nature exposure in everyday life and environments; standardised loadings = .62 and .87) and Items #3 and #4 on another (nature exposure outside everyday environments; .63 and .89). The latent factor intercorrelation was .76 (all *ps* < .001).

Thus, even though there was some indication of potential multidimensionality in the NES, a unidimensional model that accommodated the conditional structure of the items fitted the data best and was, therefore, used in all subsequent analyses. However, according to their threshold parameters, some response options were relatively uninformative, because item categories were so close to one another (which was also reflected in the relative sparseness of response option endorsement). Thus, response options 1 and 2, and 4 and 5 were each combined for Items #1 and #3, and response options 1 and 2 for Item #4. Even though this measure only slightly increased some model fit indices and slightly decreased others (Table 2), it ensured that sparseness of data did not further complicate the subsequent multigroup analyses. Thus, response options were also combined in all multigroup analyses.

3.1.2. Invariance of the cross-language results in the six countries with multiple survey languages

The MG-CFA invariance test results are presented in Supplementary Table S2. Configural and metric invariance was found for all six countries, but scalar invariance only for China. Thus, only the data from

Table 2
Analyses of the NES in the total sample and invariance of the NES concerning national groups, language, gender identity, and age.

Grouping variable and type of model	$\chi^2(df)$	CFI	TLI	RMSEA	90% *CI*	SRMR	Model comparisons			
							ΔCFI	ΔRMSEA	Configural	Metric
Total sample										
1F	6369.45(2)	.944	.831	.236	[.232, .241]	.043				
1FCE	1754.73(1)	.984	.907	.175	[.169, .182]	.021				
1FCE + CRO	1493.96(1)	.984	.902	.162	[.155, .169]	.027				
2FConL	4434.23(2)	.961	.882	.197	[.192, .202]	.042				
2FConL + CRO	3367.73(2)	.963	.889	.172	[.167, .177]	.048				
National groups										
Configural invariance	1423.31(139)	.987	.961	.107	[.102, .112]	.034				
Metric invariance	6951.05(346)	.934	.920	.153	[.150, .156]	.066	.053	.046	5300.73(207)	
Scalar invariance	19559.39(691)	.812	.886	.183	[.181, .185]	.084	.124	.030	17980.50(552)	13946.75(345)
Language										
Configural invariance	1579.37(79)	.985	.954	.115	[.111, .120]	.032				
Metric invariance	5970.23(196)	.942	.929	.144	[.141, .147]	.055	.043	.029	4266.41(117)	
Scalar invariance	17242.02(430)	.831	.906	.166	[.164, .168]	.072	.023	.022	15544.82(351)	12088.40(234)
Gender identity										
Configural invariance	1052.28(5)	.989	.959	.105	[.100, .110]	.027				
Metric invariance	863.35(11)	.991	.985	.064	[.060, .068]	.027	−.002	−.041	23.19(6)	
Scalar invariance	989.69(23)	.989	.992	.047	[.045, .050]	.028	.002	−.017	134.03(18)	120.26(12)
Age										
Configural invariance	1206.13(5)	.987	.952	.112	[.107, .118]	.027				
Metric invariance	1048.65(11)	.989	.981	.070	[.067, .074]	.028	−.002	−.042	150.04(6)	
Scalar invariance	1473.44(23)	.984	.987	.058	[.055, .060]	.031	.005	−.012	536.33(18)	414.80(12)

Note. 1F = 1-factor model; 1FCE = 1-factor model with correlated errors between Items #1 and #2, and #3 and #4; 1FCE + CRO = 1FCE model with combined response options in Items #1, #3, and #4 (see main text for details); 2FConL = correlated 2-factors model with equality constraints on the loadings of Items #1 and #3, and #2 and #4; 2FConL + CRO = 2FConL model with combined response options in Items #1, #3, and #4 (see main text for details). All *ps* of χ^2 and $\Delta\chi^2$ tests (comparisons of the multigroup models) were <.001. Gender identity compared groups of women, men, and other gender identity, age compared groups of participants with 18–24 years, 25–44 years, ≥45 years of age.

China (i.e., Mandarin, Cantonese, and English versions) were pooled for the analysis of national groups. This analysis therefore included 70 "national groups" from 65 countries.

3.1.3. *Invariance across national groups, languages, gender identities, and age groups*

3.1.3.1. Overall findings. The results of the MG-CFA analyses are presented in Table 2. The NES showed configural, but neither metric nor scalar invariance, across the 70 national groups and 40 languages.

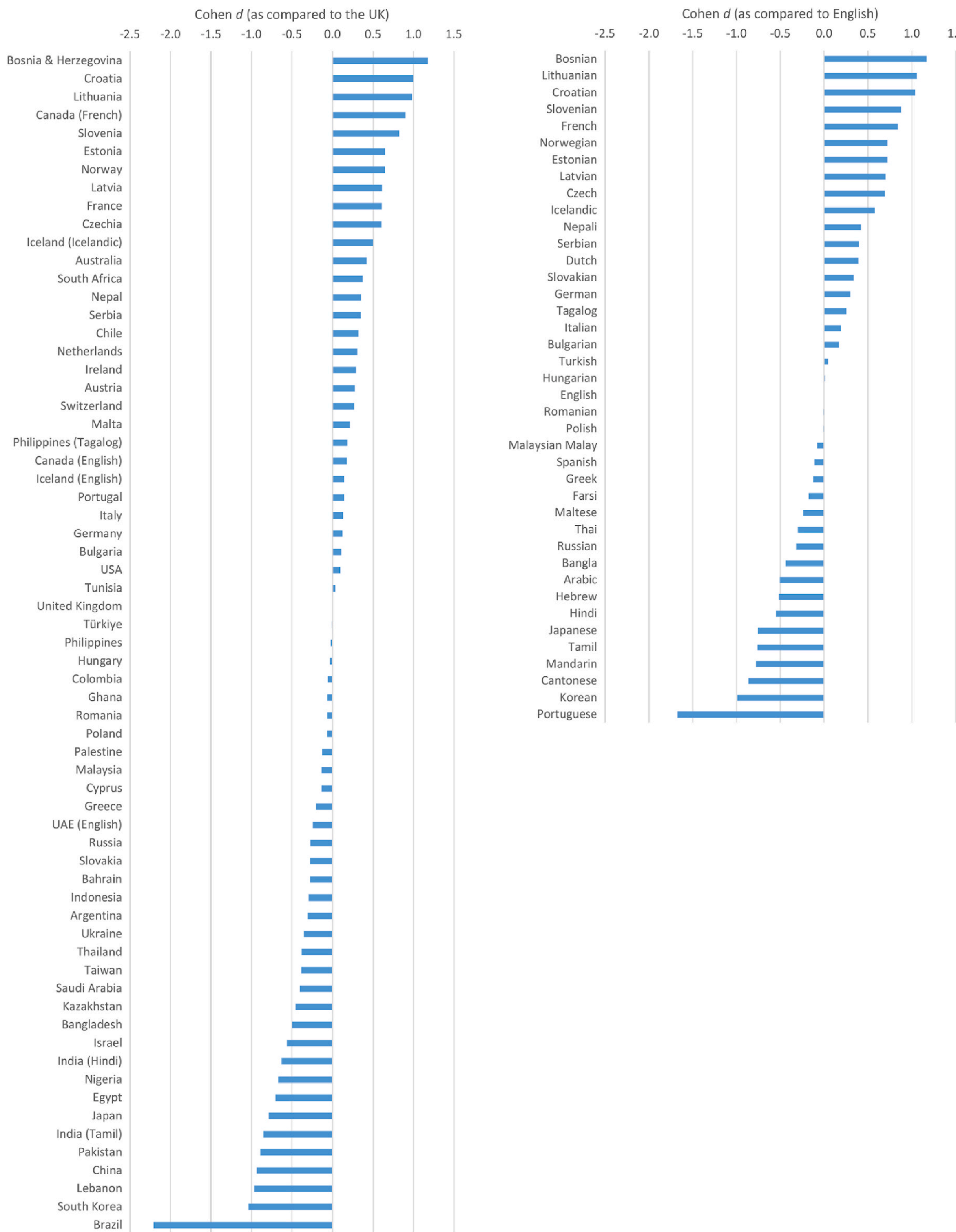

Fig. 1. *Ordering and Magnitude of Standardised Latent Mean Differences (Cohen's* d*) in the NES Between National Groups (as Compared to the UK; Left) and Languages (as Compared to English; Right).*

Note. Data from UAE (Arabic version), Ecuador, Iran, Iraq, and Spain were excluded either due to poor scale reliability or poor fit in the partial measurement model (see main text).

However, it showed configural, metric, and scalar invariance across gender identities and age groups. Scale reliability was not strong. Median scale reliability (ω total) across all national groups was .65, ranging from just .16 (UAE [Arabic version] though only reliability below .44) to .87 (Saudi Arabia; $P_{25} = .60$, $P_{75} = .74$). Nevertheless, with only 4 items and two correlated errors, scale reliability was judged to be sufficient in all national groups (except the UAE Arabic version) for further analyses for current purposes. Data from the UAE (Arabic version) were excluded in all further analyses of national groups and in the partial measurement model for languages.

3.1.3.2. National groups. The alignment method (Table S3) suggested the following descending ordering of the four NES items concerning their invariance: #2, #4, #3, #1. Item #3 had a higher summed R^2 value

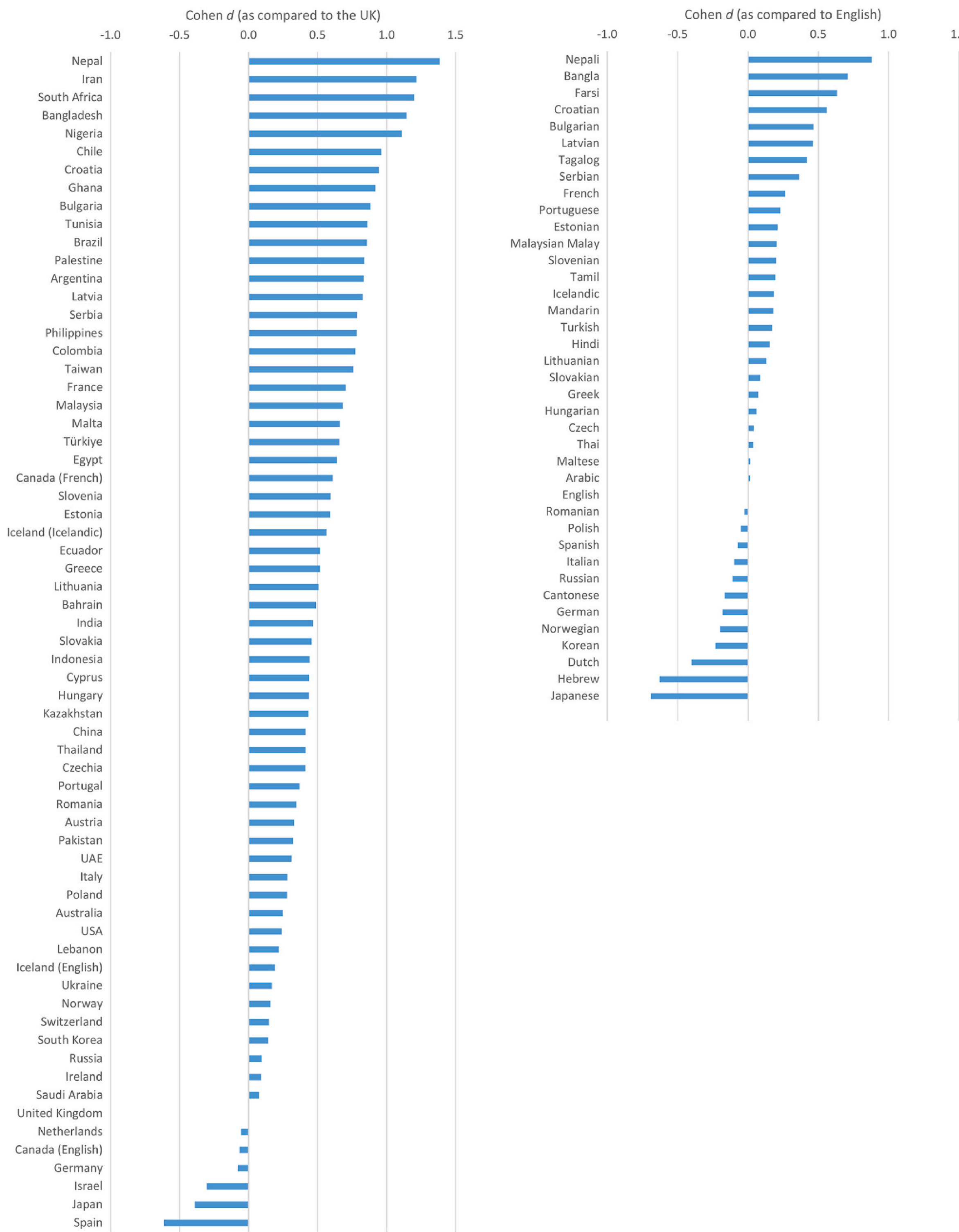

Fig. 2. *Ordering and Magnitude of Standardised Latent Mean Differences (Cohen's* d*) in the CNS-7 Between National Groups (as Compared to the UK; Left) and Languages (as Compared to English; Right).*
Note. Data from Iraq and Bosnia and Herzegovina were excluded due to the poor scale reliabilities in these countries.

than Item #4; however, Item #4 had a higher loading and exhibited invariance in its parameters in a larger number of national groups than Item #3. Items #2 and #4 were, therefore, used as item anchors in a partial scalar measurement model. Note that this indicated that the two "nature noticing" items (#2 and #4) were more invariant across national groups than the two "nature exposure" items (#1 and #3). In addition to the UAE (Arabic version), data from Ecuador, Iran, Iraq, and Spain were also subsequently excluded, as they disproportionately decreased the fit of the partial scalar measurement model, relative to their sample sizes.

For the remaining 65 national groups (including 61 single language countries and four multi-language countries), the partial scalar measurement model (using items #2 and #4 as anchors) had acceptable fit, $\chi^2 = 7722.24$, $df = 449$, CFI = .913, TLI = .924, RMSEA = .141 (.138, .144), SRMR = .051. Compared to the UK as a reference category (for purely nominal reasons [the first author is based there]), the largest positive differences in self-reported nature exposure, as reflected by the latent means on the NES, were for (in descending order) Bosnia and Herzegovina, Croatia, and Lithuania, and were in the range of $d = .98$ to 1.18 (see Fig. 2, left panel; for individual Cohen's d values, see Table S4). The largest negative differences compared to the UK were observed for Lebanon, South Korea, and, Brazil and were in the range of $d = -.97$ to -2.21.

3.1.3.3. Languages. Using Items #2 and #4 again as anchor items, the partial scalar measurement model had an acceptable fit to the data of the 40 language groups, $\chi^2 = 6959.85$, $df = 274$, CFI = .926, TLI = .935, RMSEA = .131 (.128, .134), SRMR = .048. Here, the largest positive differences in country-level latent means on the NES, compared to English (the original scale language), were observed for (in descending order) Bosnian, Lithuanian, and Croatian and were in the range of $d =$ 1.04 to 1.18 (see Fig. 2, right panel; for individual Cohen's d values, see Table S5). The largest negative differences were observed for Cantonese, Korean, and Portuguese and were in the range of $d = -.87$ to -1.68. These rankings mostly matched the rankings of the analysis of national groups (see above; but note that languages could contain a mix of different national groups, if the language in which the scale was presented there was the same; this specifically applied to English).

3.1.3.4. Gender identities and age groups. Men reported lower nature exposure (i.e., had lower NES latent means) than women (Cohen's $d = -.14$, $p < .001$), as did those with other gender identities ($d = -.25$, $p < .001$). Reported nature exposure also increased with age: age groups 25–44 years vs. 18–24 years differed by $d = .14$ ($p < .001$), whereas age groups ≥ 45 years vs. 18–24 years by $d = .48$ ($p < .001$).

3.2. Connectedness to nature scale

3.2.1. Structural analysis of the CNS-14 and CNS-7 in the total sample

A unidimensional model had a poor fit on the CNS-14, $\chi^2 = 56589.17$, $df = 75$, CFI = .921, TLI = .904, RMSEA = .115 (.114, .116), SRMR = .048, compared to the CNS-7, $\chi^2 = 5583.20$, $df = 12$, CFI = .987, TLI = .978, RMSEA = .090 (.088, .092), SRMR = .017. Additionally, the standardised loadings of Items #12 and #13, and of the negatively worded Items #4 and #14, were low ($\leq .36$). Hence, the CNS-7 was used in all subsequent analyses.

3.2.2. Invariance of the cross-language results in the six countries with multiple survey languages

The MG-CFA invariance test results of the cross-language survey presentation of the CNS-7 in Canada, China, Iceland, India, the Philippines, and the UAE are presented in Supplementary Table S6. Full scalar invariance could be assumed for all countries, except Canada and Iceland, for which metric invariance was upheld. In all countries, except Canada and Iceland, the available data were pooled for the analysis of national groups. Thus, this analysis included 67 national groups from 65 nations.

3.2.3. Invariance across national groups, languages, gender identities, and age

3.2.3.1. Overall findings. The results of the MG-CFA analyses are presented in Table 3. The CNS-7 showed configural, metric, and scalar invariance across gender identities and age groups, but only configural and metric invariance for the 67 national groups and 40 languages. Median scale reliability (ω total) across all national groups was considerably higher than the NES (.92), ranging from .64 (Iraq) to .97 (Spain; $P_{25} = .89$, $P_{75} = .93$). Bosnia and Herzegovina (.73) was the only other country below .80.

3.2.3.2. National groups. Using the alignment method, we obtained information on items and item parameters that were most invariant among the 67 national groups (Table S7). According to the summed R^2 values across the loading and all threshold parameters per item (to get an indication of overall item invariance), Items #7, #5, and #2 (in this order) appeared to be the most invariant. However, it was Items #2 and #7 whose loadings were also invariant amongst the largest number of national groups (Item #5 had the lowest number here). Hence, we opted for using Items #2 and #7 as anchor items in a partial scalar measurement model. Considering the low scale reliabilities in the Iraq and Bosnia and Herzegovina data, we excluded these national groups from this analysis. Data of these two countries were also excluded in all further analyses of national groups and in the partial measurement model of languages.

The partial scalar measurement model had a good fit to the data, $\chi^2 = 10264.83$, $df = 1164$, CFI = .982, TLI = .979, RMSEA = .095 (.094, .097), SRMR = .026. Comparing all other national groups to the UK, the ordering and magnitude of standardised latent mean differences (Cohen's d) are provided in Fig. 2 (individual Cohen's d values are provided in Table S8). The largest positive differences were observed for (in descending order) Nepal, Iran, and South Africa and were in the range of $d = 1.20$ to 1.39 (see Fig. 1, left panel), suggesting that participants from these nations reported higher connectedness to nature compared to the United Kingdom. The largest negative differences were observed for Israel, Japan, and Spain and were in the range of $d = -.30$ to $-.61$.

3.2.3.3. Languages. Using Items #2 and #7 as anchor items again, the partial scalar measurement model had a good fit on the data of the 40 language groups, $\chi^2 = 8666.51$, $df = 716$, CFI = .985, TLI = .983, RMSEA = .088 (.086, .090), SRMR = .023. Comparing all other languages to English (again the original scale language), the ordering and magnitude of standardised latent mean differences (Cohen's d) are provided in Fig. 2 (individual Cohen's d values are provided in Table S9). The largest positive differences were observed for (in descending order) Nepali, Bangla, and Farsi and were in the range of $d = .63$ to .88 (see Fig. 2, right panel). The largest negative differences were observed for Dutch, Hebrew, and Japanese and were in the range of $d = -.40$ to $-.69$. These rankings mostly matched the rankings of the analysis of national groups (see above).

3.2.3.4. Gender identities and age groups. Men reported slightly lower connectedness to nature (CNS-7 latent means) than women (Cohen's $d = -.08$, $p < .001$). Other gender identities reported similar connectedness to women ($d = .02$, $p = .79$). Connectedness to nature also increased with age: age groups 25–44 years vs. 18–24 years differed by $d = .17$ ($p < .001$), whereas age groups ≥ 45 years vs. 18–24 years by $d = .36$ ($p < .001$).

Table 3
Invariance of the CNS-7 concerning national groups, language, gender identity, and age.

Grouping variable	$\chi^2(df)$	CFI	TLI	RMSEA	90% *CI*	SRMR	Model comparisons			
							ΔCFI	ΔRMSEA	Configural	Metric
National groups										
Configural invariance	8001.09(804)	.986	.976	.103	[.101, .105]	.024				
Metric invariance	9076.08(1200)	.985	.982	.088	[.086, .090]	.028	.001	−.015	2679.88(396)	
Scalar invariance	33207.52(2520)	.941	.967	.120	[.119, .121]	.044	.044	.032	25335.58(1716)	25786.21(1320)
Language										
Configural invariance	6625.49(480)	.988	.980	.095	[.093, .097]	.020				
Metric invariance	7376.45(714)	.987	.985	.081	[.079, .083]	.024	−.005	−.014	2167.62(234)	
Scalar invariance	27691.05(1494)	.951	.972	.111	[.110, .112]	.038	.036	.020	21099.45(1014)	21599.26(780)
Gender identity										
Configural invariance	5361.43(36)	.988	.979	.088	[.086, .090]	.017				
Metric invariance	3851.56(48)	.992	.989	.065	[.063, .066]	.017	−.004	−.023	120.35(12)	
Scalar invariance	4026.67(88)	.991	.994	.049	[.047, .050]	.018	.001	−.016	766.62(52)	710.21(40)
Age										
Configural invariance	5784.07(36)	.987	.977	.092	[.090, .094]	.017				
Metric invariance	3981.35(48)	.991	.988	.066	[.064, .067]	.017	−.004	−.026	150.24(12)	
Scalar invariance	4236.02(88)	.991	.993	.050	[.049, .051]	.018	.000	−.016	837.15(52)	757.37(40)

Note. All *p*s of χ^2 and $\Delta\chi^2$ tests (model comparisons) were <.001. Gender identity compared groups of women, men, and other gender identity, age compared groups of participants with 18–24 years, 25–44 years, ≥45 years of age.

3.3. Associations between NES and CNS-7 factor scores within national groups

In the 65 national groups for which both CNS-7 and NES factor scores could be computed, the association between nature exposure and connectedness to nature ranged from $r = -.13$ (Cyprus) to .22 (Malta), with $r = .03$ in median. That is, the median correlation between these two constructs across the 65 national groups was practically nil.

3.4. Sociodemographic correlates of NES and CNS-7 factor scores

At the individual (Level-1) level, higher financial security, living in rural (vs. urban) settings, secondary/tertiary (vs. other) educational qualification, and being in a committed relationship or married (vs. other) were all associated with both greater nature exposure and connectedness to nature (see Table 4). Being a member of a racialised minority (vs. other) was associated with lower nature exposure. All associations at this individual level were, however, small and statistically explained only small amounts of the Level-1 variance. Expressed as Cohen's *ds*, the effect sizes for the dichotomous predictors of nature exposure and connectedness to nature, respectively, were as follows: urban vs. rural living setting, −.25/-.10; secondary/tertiary vs. other educational qualification, .02/.05; and committed/married vs. other, .07/.11. For racial minority (vs. other), Cohen's *d* was −.04 for nature exposure and non-significant for nature connectedness.

At the national group cluster-level (Level 2), connectedness to nature was not associated with any of the sociodemographic variables. However, higher cluster-level means of nature exposure were associated with lower cluster-level means (i.e., lower prevalence rates) of living in urban (vs. rural) settings and of being a member of a racial minority (vs. other), and thus included in the final model. In other words, countries (including those with multiple languages) with more rural respondents had higher nature exposure and those with more racial minority respondents had lower overall nature exposure, echoing the Level-1 results. These cluster-level associations were sizeable and, combined, explained 26% of the Level-2 variance.

4. Discussion

Here, we used the BINS dataset – with data from 56,968 respondents across 65 nations and 40 languages – to conduct the most comprehensive assessment of the factorial validity and measurement invariance of the NES and CNS. In terms of the NES, reliability across countries was highly variable with many countries falling below the usual thresholds of acceptability. A unidimensional model of the NES did, however, show full scalar invariance across gender identities and age groups; partial scalar invariance was also found for all languages and all but five national groups. In terms of the CNS, our results are consistent with previous work suggesting that the 14-item, unidimensional model of this instrument has poor factorial validity (Pasca et al., 2017; Rosa et al., 2022). Conversely, the CNS-7 showed full scalar invariance across gender identities and age groups, and partial scalar invariance across all languages and all but two national groups. Associations between nature exposure and connectedness to nature across nations were negligible,

Table 4
Sociodemographic correlates of nature exposure and connectedness to nature.

Predictor	Nature exposure			Connectedness to nature		
	Estimate (posterior *SD*)	95% credibility interval	*p* (one-tailed)	Estimate (posterior *SD*)	95% credibility interval	*p* (one-tailed)
Level 1: Individual level						
Financial security	**0.07 (0.004)**	**[0.06, 0.08]**	**< 0.001**	**0.02 (0.005)**	**[0.01, 0.03]**	**< 0.001**
Urbanicity	**−0.12 (0.004)**	**[-0.13, -0.12]**	**< 0.001**	**−0.05 (0.004)**	**[-0.06, -0.04]**	**< 0.001**
Education	**0.01 (0.004)**	**[0.005, 0.02]**	**< 0.001**	**0.03 (0.004)**	**[0.02, 0.04]**	**< 0.001**
Marital status	**0.04 (0.005)**	**[0.03, 0.05]**	**< 0.001**	**0.05 (0.004)**	**[0.05, 0.06]**	**< 0.001**
Racialised status	**−0.02 (0.005)**	**[-0.03, -0.01]**	**< 0.001**	.002 (.004)	[-.005, .01]	.29
Level 2: Cluster-level means						
Urbanicity	**−0.35 (0.098)**	**[-0.51, -0.14]**	**< 0.001**			
Racialised status	**−0.30 (0.103)**	**[-0.46, -0.05]**	**< 0.001**			
Random Effects						
Intercept residual variance	.74 (.09)	[.56, .92]	<.001	1.00 (.00)	NA	<.001
Explained variance (Level 1/Level 2)	2%/26%			.7%/0%		

Note. Estimates are on a standardised scale. *SD* = standard deviation. Significant (one-sided $p < .025$) estimates are highlighted in boldface.

although we did find significant (albeit weak) individual level associations between both constructs and several sociodemographic factors.

4.1. Nature exposure

We tested both a unidimensional model of the NES with all four items and a correlated 2-factor model, with equality constraints set for the two items that most closely assess "nature exposure" (#1 and #3) and "noticing nature" (#2 and #4), respectively. In the total sample, the 2-factor model had poor fit to the data, with item loadings reflecting "nature exposure" in everyday environments (#1 and #2) and outside everyday environments (#3 and #4), rather than an "exposure-noticing" split. In contrast, a unidimensional model had adequate fit to the data, although we did find that the "nature exposure" items had lower standardised loadings than the "noticing nature" items. Including correlated errors between two item pairs (#1 and #2, and #3 and #4, respectively) substantially improved fit of the unidimensional model. In short, although the NES does present some indication of possible statistical multidimensionality, this does not obviously align with face validity of the items, and a unidimensional model presented the best fit to the data anyway.

Although this unidimensional model of the NES showed configural invariance, it did not show metric or scalar invariance across national groups and languages. This suggests that, while there may be a near-universally plausible basic organisation of the nature exposure construct – as measured using the NES – each item does not contribute to the latent construct in the same way across nations or languages, making it a problematic measure to use in cross-cultural research. It was nonetheless possible to achieve partial scalar invariance across all but five of the national groups (i.e., UAE [in Arabic], Ecuador, Iran, Iraq, and Spain) represented in the analyses and all 40 languages, suggesting that it may tap a common latent construct across national groups and languages, albeit with some variation in meaning.

There were also large inter-nation and inter-language differences in NES scores. These results may reflect actual cross-national differences in exposure to natural environments, as evidenced by the large variations seen in Fig. 1. Content-wise, these differences appeared to be particularly driven by differences in "noticing nature" (Items #2 and #4 were the primary contributors to latent NES scores) but may have also been affected by differences in the meaning of "exposure to nature" across national groups (McPhie & Clarke, 2020). Here, we highlight Brazilian participants as an outlier in terms of their low latent NES scores (see Fig. 1). Reasons for this are unclear but may reflect difficulties that Brazilian participants experience in noticing natural environments, despite their proximity to such environments (see Profice et al., 2023). Alternatively, it may reflect low levels of nature exposure that many urban dwellers in low- and lower-middle income nations have due to a lack of time, money, and nearby natural environments (Awoyemi et al., 2024) or a perceived lack of safety in natural environments (e.g., due to social unrest).

Conversely, there was evidence that the unidimensional model of the NES achieved full scalar invariance across gender identities and age groups. In terms of gender identities, women reported significantly greater nature exposure than men and individuals who identified their gender in another way, although effect sizes were small. This is a curious finding, particularly as studies in Western nations have generally identified a gender gap in nature contact, with women visiting natural environments less frequently than men (e.g., Boyd et al., 2018), possibly because of experiences of fear and vulnerability in natural environments or due to societal and gendered norms that mean women often feel a lack of entitlement to leisure time in general (Day, 2000). It is possible that this discrepancy across studies is due to the inclusion of "noticing nature" in the NES and possibly women having a greater tendency to "notice nature" because they may be more sensitive to particular settings that may evoke fear, anxiety, and negative emotions (van den Berg & ter Heijne, 2005). In terms of age, self-reported nature exposure using the NES generally increased from emerging to older adulthood. It is likely that the latter group has greater time and opportunities to engage with nature (Freeman et al., 2019) and may also have a fuller understanding of the natural world, which in turn may enhance their abilities to "notice" the natural environment (Ojala, 2009).

4.2. Connectedness to nature

The CNS results indicated that a unidimensional model including all 14 items had poor fit. Although the 14-item model demonstrated adequate fit in some previous research (e.g., Li & Wu, 2016; Mayer & Frantz, 2004; Pessoa et al., 2016), our findings corroborate more recent difficulties replicating this model (e.g., Navarro et al., 2017; Olivos et al., 2013; Pearce et al., 2022). As Pasca et al. (2017) have suggested, it is highly likely that some CNS items either perform poorly – for linguistic, conceptual, or semantic reasons – or are redundant in some national contexts. Adopting an Item Response Theory approach also suggested that some items may inadequately discriminate between individuals who vary in their degree of connectedness to nature (Pasca et al., 2017). For these reasons, Pasca et al. (2017) recommended using a truncated version of the CNS that includes only seven of the 14 original items, which has been found to have a unidimensional factor structure in previous work (Rosa et al., 2022).

Using this CNS-7, our results suggested that configural and metric invariance was supported across nations, languages, gender identities, and age groups. In terms of national groups and languages, the lack of full scalar invariance is consistent with previous work in seven European nations, where only configural and metric invariance was found (Navarro et al., 2022). One possible reason for the lack of scalar invariance of the CNS-7 across national groups and languages is that this instrument – and indeed the construct of connectedness to nature itself – is steeped in a boundary distinction between humans and the natural environment (i.e., that one can be distinct or disconnected from nature). As Fletcher (2017, p. 228) has suggested, however, this view is grounded in a "culturally specific … conceptual dichotomy between opposing realms of 'nature' and 'culture'" that is characteristic of wealthy, Western nations. In other words, the suggestion that humans can be separate from nature – or, indeed that humans are not nature – may be a cultural worldview with limited global application, which in turn may explain the lack of scalar invariance in relation to the CNS-7 in the present study.

Having said this, full scalar invariance is often an unrealistic goal for datasets with a large number of groups (Marsh et al., 2018). Importantly, our results also suggested that it was possible to achieve partial scalar invariance of the CNS-7 across all but two national groups (i.e., Iraq and Bosnia and Herzegovina, respectively) and all 40 languages represented in the BINS. This is important theoretically because it suggests that the CNS-7 can be used to measure a latent construct of connectedness to nature that may have near-universal applicability, albeit with some possible loss of meaning. From a practical point-of-view, achieving partial scalar invariance means that we were able to compare latent CNS-7 means across national groups and languages, with our results showing large cross-national and cross-language differences in CNS-7 latent means. Understanding why such differences exist is, however, more difficult and only preliminary explanations can be put forward based on the present data.

Richardson, Hamlin, Elliott, and White (2022), for instance, suggested that lower country-level nature connectedness may reflect historical interactions with, and attitudes towards, the natural world. Observing that all six of the countries with the lowest nature connectedness scores in an 18-country study by White et al. (2021) were at some time subject to British rule, Richardson, Hamlin, Elliott, and White (2022) wondered whether early industrialisation and urbanisation of the UK, and resource extraction and exploitation of its colonies, encouraged seeing nature as external and separate to human lives. However, although the UK again had very low levels of CNS in the present research, as did some of its former colonies (e.g., Australia, Canada [English], Ireland, and the USA), other former British colonies, notably on the African continent, including South Africa, Nigeria, and Ghana, were among the countries with the highest connectedness to nature. An alternative suggestion, therefore, is that it is the English language version that results in lower CNS scores, an idea supported by the English versus French/Icelandic data from Canada and Iceland data, but undermined by the fact that these three African countries also used the English language version.

More broadly, therefore, it appears that the variation in connectedness to nature across nations and languages may reflect differences in the ways that connectedness to nature is constructed, negotiated, and experienced by different communities (see McPhie & Clarke, 2020). That is, what it means to be "connected to nature" or experience a sense of oneness with nature likely varies across nations and/or cultures, which results in the type of variation that can be seen in Fig. 2 when individuals are asked to self-report their experiences. It is also possible that cultural practices and traditions that foster both connectedness to nature, as well as the ability to articulate that connectedness, varies across national groups (Keaulana et al., 2021). For instance, there is some evidence to suggest that individuals in Nepal and Bangladesh – two nations that had very high latent CNS-7 scores in the present study – live in ways that are intimately connected to the natural world (Widdop Quinton & Khatun, 2020). Further work is clearly needed to explore these issues in greater depth.

In terms of gender identities, we found that the CNS-7 showed full scalar invariance across women, men, and individuals who identified their gender in another way. The CNS-7 taps a common underlying construct of connectedness to nature that is not differentially affected by gender identities. Women reported higher nature connectedness than men, consistent with previous work showing that women have greater environmental concern (e.g., Xiao & McCright, 2015) and dispositional empathy with nature (Tam, 2013), though effect sizes were relatively small. Additionally, we found that the CNS-7 was fully invariant across age groups, with connectedness to nature generally increasing from emerging adulthood to older adulthood, though again group differences were relatively small.

4.3. Correlates of nature exposure and connectedness

Contrary to our hypothesis, the median correlation between nature exposure and nature connectedness, as measured using the NES and CNS, across nations was practically nil. This finding stands in contrast to previous cross-sectional (e.g., Fränkel et al., 2019; Martin et al., 2020) and experimental studies (Sheffield et al., 2022) that have shown these constructs to be weakly-to-moderately correlated. Moreover, where studies have assessed these constructs using the NES and CNS, respectively, reported associations have tended to be moderate-to-large (Baceviciene et al., 2021; Picanço et al., 2024; Swami et al., 2016; Swami, Barron, et al., 2020). In these studies, however, the significant associations may have been inflated through the use of ecological correlations in singular nations.

Instead, the present results suggest that the true variation in the association between nature exposure (measured using the NES) and connectedness to nature (measured using the CNS-7) across nations may be relatively wide. This raises questions about what exactly is being measured by the NES, and how. While we acknowledge the rationale for the scale to want to incorporate the three types of exposure explored in the literature (local, active visits, and awareness) into a single measure, the way this is operationalised is logically problematic because there is no longer any single underlying latent construct. While Items #2 and #4 both tap into "nature-noticing" using the same response options, Items #1 and #3, by design, are interested in different types of "nature-exposure" and use different response options. It is perhaps not surprising, then, that the reliability across many countries was low.

Although there was some statistical evidence that the items could be collapsed into a unidimensional scale representing a single underlying factor, it was perhaps not surprising that Items #2 and #4 were the strongest since they were the only two measuring the same thing in the same way. By contrast, the 4-item scale lacks clear conceptual or face validity. So, if the NES is not measuring nature exposure, what is it measuring? One possibility is that it is heuristically measuring a general attitude towards the natural world with people generally interested in nature answering relatively positively to the four items and *vice versa*. If this were the case, however, one might still expect stronger associations between NES scores and connectedness to nature. Another possibility is that the NES is measuring different types of "exposure" in a single metric, and which form of exposure is most salient or relevant may depend on the national or linguistic context.

In terms of relations of the two instruments to selected demographics, both greater nature exposure and connectedness to nature were significantly (but weakly) associated with greater financial security, rural residence (versus urban residence), higher education, being in a committed relationship (versus being single), and being in a racial majority in a specific country. Broadly speaking, the significant associations with financial security, higher education, and racial majority status reflect known socioeconomic inequities in terms of the distribution of, and outcomes of exposure to, natural environments (e.g., Gerrish & Watkins, 2018; Murdock, 2019). Likewise, the significant association with rurality is perhaps to be expected and consistent with previous findings (e.g., Carrus et al., 2020; Martin & Czellar, 2017). The finding that those in committed relationships were more likely to report greater connectedness to nature and nature exposure than those who were single is also consistent with existing research (e.g., Teixeira et al., 2023) and may reflect the beneficial impact of social support in nature engagement. Racialised minority individuals may also experience natural environments differently to majority groups (e.g., in terms of perceived safety, comfort, a sense of belonging) due to historic and contemporary inequities stemming from structural racism (Collier, 2022; Roberts et al., 2023), which impacts ongoing nature exposure.

4.4. Constraints on generalisability and directions for future research

Although the present work provides one of the largest cross-national databases on nature exposure and connectedness to nature, our findings should be considered in light of a number of constraints on their generalisability (Simons et al., 2017). First, our sampling strategy was opportunistic in most cases and, as such, the individual samples should not be considered representative of a particular nation. This may reduce the generalisability of our findings, particularly when making comparisons across nations or linguistic groups. Relatedly, although one of the strengths of the BINS dataset is the focus on operational equivalence across research sites (Swami et al., 2022), we cannot entirely rule out small differences in recruitment and survey completion (e.g., in terms of online versus offline completion, participant remuneration, specific recruitment methods). Also related to recruitment, because the BINS dataset was researcher-crowdsourced, our data was under-represented in several world regions (e.g., Africa, Central Asia, the Caribbean, Central America), though this is a common limitation of many large-scale, cross-national studies (Krys et al., 2024).

Another constraint on generalisability was that specific conditions during the period of data collection – which extended over 15 months and took place in the shadow of the COVID-19 pandemic – may have varied substantially across nations. This is particularly important when considering that pandemic-related policies may have directly impacted one's ability to spend time in nature (e.g., due to periods of lockdown; Stieger et al., 2021). These varying conditions make it difficult to know to what extent our data are temporally reliable and whether specific pandemic-related experiences (e.g., being in lockdown, severity of the pandemic, national and international responses to the pandemic, none of which were measured in our survey) may have affected our findings. Still, given the consistency of factor structures across groups, any biases in results are likely to be reflected in latent group differences.

Finally, because the BINS dataset consists of self-reported data, we cannot rule out common-method biases. On this note, there was some evidence of response-scale spareness in terms of the NES (i.e., some response options were rarely utilised), which may have affected our findings. Yet, even though some response options had to be combined to make the multigroup analyses feasible, this measure is not needed when utilising the instrument. We still recommend using its 5-point response scale, but expect that some response options will only be seldomly used. Also, there was evidence of insufficient fit of a unidimensional model for the NES in a number of countries, which may further limit its applicability.

Our findings also raise several important questions that could be more fully answered in future research. For instance, it is unclear at present why instrument composite reliabilities were less-than-adequate in some linguistic or national groups (e.g., the Arabic NES in the United Arab Emirates or the CNS in Iraq and Bosnia and Herzegovina). Likewise, while our work provides a useful starting point, much more can be done to interrogate and understand latent national and linguistic differences in nature exposure and connectedness to nature. More generally, it remains important to explore the diverse ways that "nature" and "nature connectedness" are conceptualised, understood, and lived in diverse cultural contexts, as well as the ways in which nuances in understandings of "nature" affect human behaviour (Droz et al., 2022). Doing so will help researchers and practitioners ensure that voices from diverse populations worldwide are not rendered invisible or muffled in the scientific literature.

4.5. Conclusion

These constraints on generalisability notwithstanding, the present work suggests that the CNS-7 is a useful tool for assessing a latent connectedness to nature construct across national and linguistic groups, gender identities, and adult age groups. While our statistical analyses also pointed to the potential use of the NES to generate a univariate score representing nature exposure, important questions remain around this instrument's face and nomological validity. While we conclude that the CNS-7 can be used in cross-national and cross-linguistic research with no substantive loss of meaning, we also caution that our work was not set up to investigate and understand localised, cultural meanings and experiences of connectedness to nature. Further work is needed to robustly capture nature exposure. One may flip our methodological design and utilise more emic approaches in the future to fully understand geographic, cultural, and linguistic variations in how nature is experienced and how connectedness to nature manifests (e.g., Sedawi et al., 2021).

CRediT authorship contribution statement

Viren Swami: Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Mathew P. White:** Writing – original draft, Investigation. **Martin Voracek:** Writing – review & editing, Validation, Methodology, Investigation, Data curation, Conceptualization. **Ulrich S. Tran:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Toivo Aavik:** Writing – review & editing, Investigation, Data curation. **Hamed Abdollahpour Ranjbar:** Writing – review & editing, Investigation, Data curation. **Sulaiman Olanrewaju Adebayo:** Writing – review & editing, Investigation, Data curation. **Reza Afhami:** Writing – review & editing, Investigation, Data curation. **Oli Ahmed:** Writing – review & editing, Investigation, Data curation. **Annie Aimé:** Writing – review & editing, Investigation, Data curation. **Marwan Akel:** Writing – review & editing, Investigation, Data curation. **Hussam Al Halbusi:** Writing – review & editing, Investigation, Data curation. **George Alexias:** Writing – review & editing, Investigation, Data curation. **Khawla F. Ali:** Writing – review & editing, Investigation, Data curation. **Nursel Alp-Dal:** Writing – review & editing, Investigation, Data curation. **Anas B. Alsalhani:** Writing – review & editing, Investigation, Data curation. **Sara Álvarez-Solas:** Writing – review & editing, Investigation, Data curation. **Ana Carolina Soares Amaral:** Writing – review & editing, Investigation, Data curation. **Sonny Andrianto:** Writing – review & editing, Investigation, Data curation. **Trefor Aspden:** Writing – review & editing, Investigation, Data curation. **Marios Argyrides:** Writing – review & editing, Investigation, Data curation. **John Jamir Benzon R. Aruta:** Writing – review & editing, Investigation, Data curation. **Stephen Atkin:** Writing – review & editing, Investigation, Data curation. **Olusola Ayandele:** Writing – review & editing, Investigation, Data curation. **Migle Baceviciene:** Writing – review & editing, Investigation, Data curation. **Radvan Bahbouh:** Writing – review & editing, Investigation, Data curation. **Andrea Ballesio:** Writing – review & editing, Investigation, Data curation. **David Barron:** Writing – review & editing, Investigation, Data curation. **Ashleigh Bellard:** Writing – review & editing, Investigation, Data curation, Writing – review & editing, Investigation, Data curation. **SóleySesselja Bender:** Writing – review & editing, Investigation, Data curation. **Kerime Derya Beydağ:** Writing – review & editing, Investigation, Data curation. **Gorana Birovljević:** Writing – review & editing, Investigation, Data curation. **Marie-Ève Blackburn:** Writing – review & editing, Investigation, Data curation. **Teresita Borja-Alvarez:** Writing – review & editing, Investigation, Data curation. **Joanna Borowiec:** Writing – review & editing, Data curation. **Miroslava Bozogáňová:** Writing – review & editing, Investigation, Data curation. **Solfrid Bratland-Sanda:** Writing – review & editing, Investigation, Data curation. **MatthewH.E.M. Browning:** Writing – review & editing, Investigation, Data curation. **Marina Burakova:** Writing – review & editing, Investigation, Data curation. **Yeliz Çakır-Koçak:** Writing – review & editing, Investigation, Data curation. **Pablo Camacho:** Writing – review & editing, Investigation, Data curation. **Vittorio Emanuele Camilleri:** Writing – review & editing, Investigation, Data curation. **Valentina Cazzato:** Writing – review & editing, Investigation, Data curation. **Silvia Cerea:** Writing – review & editing, Investigation, Data curation. **Apitchaya Chaiwutikornwanich:** Writing – review & editing, Investigation, Data curation. **Trawin Chaleeraktrakoon:** Writing – review & editing, Investigation, Data curation. **Tim Chambers:** Writing – review & editing, Investigation, Data curation. **Qing-Wei Chen:** Writing – review & editing, Investigation, Data curation. **Xin Chen:** Writing – review & editing, Investigation, Data curation. **Chin-Lung Chien:** Writing – review & editing, Investigation, Data curation. **Phatthanakit Chobthamkit:** Writing – review & editing, Investigation, Data curation. **Bovornpot Choompunuch:** Writing – review & editing, Investigation, Data curation. **Emilio J. Compte:** Writing – review & editing, Investigation, Data curation. **Jennifer Corrigan:** Writing – review & editing, Investigation, Data curation. **Getrude Cosmas:** Writing – review & editing, Investigation, Data curation. **Richard G. Cowden:** Writing – review & editing, Investigation, Data curation. **Kamila Czepczor-Bernat:** Writing – review & editing, Investigation, Data curation. **Marcin Czub:** Writing – review & editing, Investigation, Data curation. **Wanderson Roberto da Silva:** Writing – review & editing, Investigation, Data curation. **Mahboubeh Dadfar:** Writing – review & editing, Investigation, Data curation. **Simon E. Dalley:** Writing – review & editing, Investigation, Data curation. **Lionel Dany:** Writing – review & editing, Investigation, Data curation. **Jesus Alfonso D. Datu:** Writing – review & editing, Investigation, Data curation. **Pedro Henrique Berbert de Carvalho:** Writing – review & editing, Investigation, Data curation. **Gabriel Lins de Holanda Coelho:** Writing – review & editing, Investigation, Data curation. **Avila Odia S. De Jesus:** Writing – review & editing, Investigation, Data curation. **Sonia Harzallah Debbabi:** Writing – review & editing, Investigation, Data curation. **Sandesh Dhakal:** Writing – review & editing, Investigation, Data curation. **Francesca Di Bernardo:** Writing – review & editing, Investigation, Data curation. **Donka D. Dimitrova:** Writing – review & editing, Investigation, Data curation. **Jacinthe Dion:** Writing – review & editing, Investigation, Data curation. **Barnaby Dixson:** Writing – review & editing, Investigation, Data curation. **Stacey M. Donofrio:** Writing – review & editing, Investigation, Data curation. **Marius Drysch:** Writing – review & editing, Investigation, Data curation. **Hongfei Du:** Writing – review & editing, Investigation, Data curation. **Angel M. Dzhambov:** Writing – review & editing, Investigation, Data curation. **Claire El-Jor:** Writing – review & editing, Investigation, Data curation. **Violeta Enea:** Writing – review & editing, Investigation, Data curation. **Mehmet Eskin:** Writing – review & editing, Investigation, Data curation. **Farinaz Farbod:** Writing – review & editing, Investigation, Data curation. **Lorleen Farrugia:** Writing – review & editing, Investigation, Conceptualization. **Leonie Fian:** Writing – review & editing, Investigation, Data curation. **Maryanne L. Fisher:** Writing – review & editing, Investigation, Data curation. **Michał Folwarczny:** Writing – review & editing, Investigation, Data curation, Writing – review & editing, Investigation, Data curation. **David A. Frederick:** Writing – review & editing, Investigation, Data curation. **Adrian Furnham:** Writing – review & editing, Investigation, Data curation. **Antonio Alías García:** Writing – review & editing, Investigation, Data curation. **Shulamit Geller:** Writing – review & editing, Investigation, Data curation. **Marta Ghisi:** Writing – review & editing, Investigation, Data curation. **Alireza Ghorbani:** Writing – review & editing, Investigation, Conceptualization. **Maria Angeles Gomez Martinez:** Writing – review & editing, Investigation, Data curation. **Sarah Gradidge:** Writing – review & editing, Investigation, Data curation. **Sylvie Graf:** Writing – review & editing, Investigation, Data curation. **Caterina Grano:** Writing – review & editing, Investigation, Data curation. **Gyöngyvér Gyene:** Writing – review & editing, Investigation, Data curation. **Souheil Hallit:** Writing – review & editing, Investigation, Data curation. **Motasem Hamdan:** Writing – review & editing, Investigation, Data curation. **Jonathan E. Handelzalts:** Writing – review & editing, Investigation, Data curation. **PaulH.P. Hanel:** Writing – review & editing, Investigation, Data curation. **Steven R. Hawks:** Writing – review & editing, Investigation, Data curation. **Issa Hekmati:** Writing – review & editing, Investigation, Data curation. **Mai Helmy:** Writing – review & editing, Investigation, Data curation. **Tetiana Hill:** Writing – review & editing, Investigation, Data curation. **Farah Hina:** Writing – review & editing, Investigation, Data curation. **Geraldine Holenweger:** Writing – review & editing, Investigation, Data curation. **Martina Hřebíčková:** Writing – review & editing, Investigation, Data curation. **Olasupo Augustine Ijabadeniyi:** Writing – review & editing, Investigation, Data curation. **Asma Imam:** Writing – review & editing, Investigation, Data curation. **Başak İnce:** Writing – review & editing, Investigation, Data curation. **Natalia Irrazabal:** Writing – review & editing, Investigation, Data curation. **Rasa Jankauskiene:** Writing – review & editing, Investigation, Data curation. **Ding-Yu Jiang:** Writing – review & editing, Investigation, Data curation. **Evan M. Johnson:** Writing – review & editing, Investigation, Data curation. **Veljko Jovanović:** Writing – review & editing, Investigation, Data curation, Writing – review & editing, Investigation, Data curation. **Marija Jović:** Writing – review & editing, Investigation, Data curation. **Marko Jović:** Writing – review & editing, Investigation, Data curation, Writing – review & editing, Investigation, Data curation. **Alessandra Costa Pereira Junqueira:** Writing – review & editing, Investigation, Data curation. **Lisa-Marie Kahle:** Writing – review & editing, Investigation, Data curation. **Adam Kantanista:** Writing – review & editing, Investigation, Data curation. **Ahmet Karakiraz:** Writing – review & editing, Investigation, Data curation. **Ayşe Nur Karkin:** Writing – review & editing, Investigation, Conceptualization. **Erich Kasten:** Writing – review & editing, Investigation, Data curation. **Salam Khatib:** Writing – review & editing, Investigation, Data curation. **Nuannut Khieowan:** Writing – review & editing, Investigation, Data curation. **Patricia Joseph Kimong:** Writing – review & editing, Investigation, Data curation. **Litza Kiropoulos:** Writing – review & editing, Investigation, Data curation. **Joshua Knittel:** Writing – review & editing, Investigation, Data curation. **Neena Kohli:** Writing – review & editing, Investigation, Data curation. **Mirjam Koprivnik:** Writing – review & editing, Investigation, Data curation. **Aituar Kospakov:** Writing – review & editing, Investigation, Data curation. **Isabel Krug:** Writing – review & editing, Investigation, Data curation. **Garry Kuan:** Writing – review & editing, Investigation, Data curation. **Yee Cheng Kueh:** Writing – review & editing, Investigation, Data curation. **Omar Kujan:** Writing – review & editing, Investigation, Data curation. **Miljana Kukić:** Writing – review & editing, Investigation, Data curation, Writing – review & editing, Investigation, Data curation. **Sanjay Kumar:** Writing – review & editing, Investigation, Data curation. **Vipul Kumar:** Writing – review & editing, Investigation, Data curation. **Nishtha Lamba:** Writing – review & editing, Investigation, Data curation. **Mary Anne Lauri:** Writing – review & editing, Investigation, Data curation. **Maria Fernanda Laus:** Writing – review & editing, Investigation, Data curation. **Liza April LeBlanc:** Writing – review & editing, Investigation, Data curation. **Hyejoo J. Lee:** Writing – review & editing, Investigation, Data curation. **Małgorzata Lipowska:** Writing – review & editing, Investigation, Data curation. **Mariusz Lipowski:** Writing – review & editing, Investigation, Data curation. **Caterina Lombardo:** Writing – review & editing, Investigation, Data curation. **Andrea Lukács:** Writing – review & editing, Investigation, Data curation. **Christophe Maïano:** Writing – review & editing, Investigation, Data curation. **Sadia Malik:** Writing – review & editing, Investigation, Data curation. **Mandar Manjary:** Writing – review & editing, Investigation, Data curation. **Lidia Márquez Baldó:** Writing – review & editing, Investigation, Data curation. **Martha Martinez-Banfi:** Writing – review & editing, Investigation, Data curation. **Karlijn Massar:** Writing – review & editing, Investigation, Data curation. **Camilla Matera:** Writing – review & editing, Investigation, Data curation. **Olivia McAnirlin:** Writing – review & editing, Investigation, Data curation. **Moisés Roberto Mebarak:** Writing – review & editing, Investigation, Data curation. **Anwar Mechri:** Writing – review & editing, Investigation, Data curation. **Juliana Fernandes Filgueiras Meireles:** Writing – review & editing, Investigation, Data curation. **Norbert Mesko:** Writing – review & editing, Investigation, Data curation. **Jacqueline Mills:** Writing – review & editing, Investigation, Data curation. **Maya Miyairi:** Writing – review & editing, Investigation, Data curation. **Ritu Modi:** Writing – review & editing, Investigation, Data curation. **Adriana Modrzejewska:** Writing – review & editing, Investigation, Data curation. **Justyna Modrzejewska:** Writing – review & editing, Investigation, Data curation. **Kate E. Mulgrew:** Writing – review & editing, Investigation, Data curation. **Taryn A. Myers:** Writing – review & editing, Investigation, Data curation. **Hikari Namatame:** Writing – review & editing, Investigation, Data curation. **Mohammad Zakaria Nassani:** Writing – review & editing, Investigation, Data curation. **Amanda Nerini:** Writing – review & editing, Investigation, Data curation. **Félix Neto:** Writing – review & editing, Investigation, Data curation. **Joana Neto:** Writing – review & editing, Investigation, Data curation. **Angela Nogueira Neves:** Writing – review & editing, Investigation, Data curation. **Siu-Kuen Ng:** Writing – review & editing, Investigation, Data curation. **Devi Nithiya:** Writing – review & editing, Investigation, Data curation. **Jiaqing O:** Writing – review & editing, Investigation, Data curation. **Sahar Obeid:** Writing – review & editing, Investigation, Data curation. **Camila Oda-Montecinos:** Writing – review & editing, Investigation, Data curation. **Peter Olamakinde Olapegba:** Writing – review & editing, Investigation, Data curation. **Tosin Tunrayo Olonisakin:** Writing – review & editing, Investigation, Data curation. **Salma Samir Omar:** Writing – review & editing, Investigation, Data curation. **Brynja Örlygsdóttir:** Writing – review & editing, Investigation, Data curation. **Emrah Özsoy:** Writing – review & editing, Investigation, Data curation. **Tobias Otterbring:** Writing – review & editing, Investigation, Data curation. **Sabine Pahl:** Writing – review & editing, Investigation, Data curation. **Maria Serena Panasiti:** Writing – review & editing, Investigation, Data curation. **Yonguk Park:** Writing – review & editing, Investigation, Data curation. **Muhammad Mainuddin Patwary:** Writing – review & editing, Investigation, Data curation. **Tatiana Pethö:** Writing – review & editing, Investigation, Data curation. **Nadezhda Petrova:** Writing – review & editing, Investigation, Data curation. **Jakob Pietschnig:** Writing – review & editing, Investigation, Data curation. **Sadaf Pourmahmoud:** Writing – review & editing, Investigation, Data curation. **Vishnunarayan Girishan Prabhu:** Writing – review & editing, Investigation, Data curation. **Vita Poštuvan:** Writing – review & editing, Investigation, Data curation. **Pavol Prokop:** Writing – review & editing, Investigation, Data curation. **Virginia L. Ramseyer Winter:** Writing – review & editing, Investigation, Data curation. **Magdalena Razmus:** Writing – review & editing, Investigation, Data curation. **Taotao Ru:** Writing – review & editing, Investigation, Data curation. **Mirjana Rupar:** Writing – review & editing, Investigation, Data curation. **Reza N. Sahlan:** Writing – review & editing, Investigation, Data curation. **Mohammad Salah Hassan:** Writing – review & editing, Investigation, Data curation. **Anđela Šalov:** Writing – review & editing, Investigation, Data curation. **Saphal Sapkota:** Writing – review & editing, Investigation, Data curation. **Jacob Owusu Sarfo:** Writing – review & editing, Investigation, Data curation. **Yoko Sawamiya:** Writing – review & editing, Investigation, Data curation. **Katrin Schaefer:** Writing – review & editing, Investigation, Data curation. **Michael Schulte-Mecklenbeck:** Writing – review & editing, Investigation, Data curation. **Veya Seekis:** Writing – review & editing, Investigation, Data curation. **Kerim Selvi:** Writing – review & editing, Investigation, Data curation. **Mehdi Sharifi:** Writing – review & editing, Investigation, Data curation. **Anita Shrivastava:** Writing – review & editing, Investigation, Data curation. **Rumana Ferdousi Siddique:** Writing – review & editing, Investigation, Data curation. **Valdimar Sigurdsson:** Writing – review & editing, Investigation, Data curation. **Vineta Silkane:** Writing – review & editing, Investigation, Data curation. **Ana Šimunić:** Writing – review & editing, Investigation, Data curation. **Govind Singh:** Writing – review & editing, Investigation, Data curation. **Alena Slezáčková:** Writing – review & editing, Investigation, Data curation. **Christine Sundgot-Borgen:** Writing – review & editing, Investigation, Data curation. **Gill Ten Hoor:** Writing – review & editing, Investigation, Data curation. **Passagorn Tevichapong:** Writing – review & editing, Investigation, Data curation. **Arun Tipandjan:** Writing – review & editing, Investigation, Data curation. **Jennifer Todd:** Writing – review & editing, Investigation, Data curation. **Constantinos Togas:** Writing – review & editing, Investigation, Data curation. **Fernando Tonini:** Writing – review & editing, Investigation, Data curation. **Juan Camilo Tovar-Castro:** Writing – review & editing, Investigation, Data curation. **Lise Katrine Jepsen Trangsrud:** Writing – review & editing, Investigation, Data curation. **Pankaj Tripathi:** Writing – review & editing, Investigation, Data curation. **Otilia Tudorel:** Writing – review & editing, Investigation, Data curation. **Tracy L. Tylka:** Writing – review & editing, Investigation, Data curation. **Anar Uyzbayeva:** Writing – review & editing, Investigation, Data curation. **Zahir Vally:** Writing – review & editing, Investigation, Data curation. **Edmunds Vanags:** Writing – review & editing, Investigation, Data curation. **Luis Diego Vega:** Writing – review & editing, Investigation, Data curation. **Aitor Vicente-Arruebarrena:** Writing – review & editing, Investigation, Data curation. **Jose Vidal-Mollón:** Writing – review & editing, Investigation, Data curation. **Roosevelt Vilar:** Writing – review & editing, Investigation, Data curation. **Hyxia Villegas:** Writing – review & editing, Investigation, Data curation. **Mona Vintilă:** Writing – review & editing, Investigation, Data curation. **Christoph Wallner:** Writing – review & editing, Investigation, Data curation. **Simon Whitebridge:** Writing – review & editing, Investigation, Data curation. **Sonja Windhager:** Writing – review & editing, Investigation, Data curation. **Kah Yan Wong:** Writing – review & editing, Investigation, Data curation. **Eric Kenson Yau:** Writing – review & editing, Investigation, Data curation. **Yuko Yamamiya:** Writing – review & editing, Investigation, Data curation. **Victoria Wai Lan Yeung:** Writing – review & editing, Investigation, Data curation. **Marcelo Callegari Zanetti:** Writing – review & editing, Investigation, Data curation. **Magdalena Zawisza:** Writing – review & editing, Investigation, Data curation. **Nadine Zeeni:** Writing – review & editing, Investigation, Data curation. **Martina Zvaríková:** Writing – review & editing, Investigation, Data curation. **Stefan Stieger:** Writing – review & editing, Investigation, Data curation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2024.102432.

Appendix 1

The Nature Exposure Scale (NES)

Two of the four NES items ask about nature exposure in one's everyday life and environments: Item #1 "In your everyday home, travel, and work environments and activities, please rate your level of exposure to 'natural environments" with options ranging from '*High (most of my everyday environment is natural)*' (5)', to '*Low (very little of my everyday environment is natural)*' (1), and Item #2 "How much do you notice the natural environments in your everyday life?" with options ranging from '*A great deal*' (5), to '*Not much*' (1). Two further items ask about nature exposure during excursions outside of one's everyday environments: Item #3 "Please rate the frequency (how often) of exposure to nature-rich environments outside of your everyday environment" with options ranging from '*High (once a month or more often)*' (5), to '*Low (once a year or less)*' (1), and Item #4 "How much notice would you take of nature in these environments?" with the same response options as item 2.

The Connectedness to Nature Scale (CNS)

The 14 items of the CNS are as follows, with response options ranging from 1 (*strongly disagree*) to 5 (*strongly agree*): #1 "I often feel a sense of oneness with the natural world around me", #2 "I think of the natural world as a community to which I belong", #3 "I recognize and appreciate the intelligence of other living organisms", #4 "I often feel disconnected from nature", #5 "When I think of my life, I imagine myself to be part of a larger cyclical process of living", #6 "I often feel a kinship with animals and plants", #7 "I feel as though I belong to the Earth as equally as it belongs to me", #8 "I have a deep understanding of how my actions affect the natural world", #9 "I often feel part of the web of life", #10 "I feel that all inhabitants of Earth, human, and nonhuman, share a common 'life force'", #11 "Like a tree can be part of a forest, I feel embedded within the broader natural world", #12 "When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature", #13 "I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees", and #14 "My personal welfare is independent of the welfare of the natural world".

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