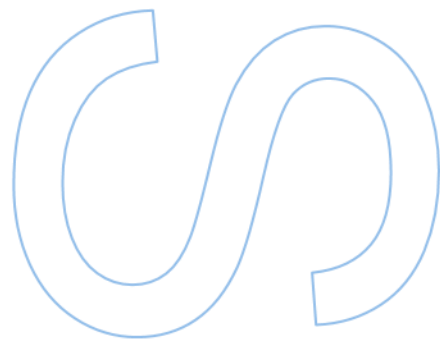
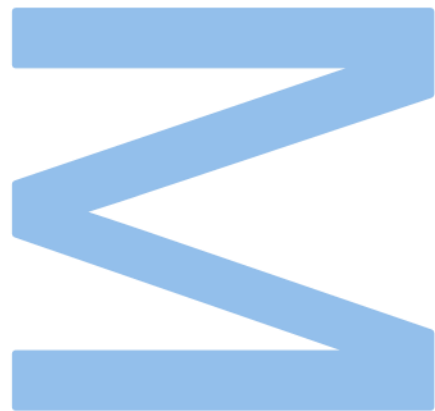


Climate Change Denial: How Low Understanding and False Beliefs Sustain Public Inaction

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2025



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Master's thesis carried out as part of the Master in Science Education and Communication
Science Education Unit
2025

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To future generations.

Acknowledgements

My favourite Portuguese poet, Fernando Pessoa, says throughout his rich poetic repertoire that humans cannot confine themselves within finite walls; we are marbled by each and every person who shares life with us.

At any moment, everyone have carved even the slightest details that make us what we authentically are.

My greatest gratitude to those who have sparked the most out of my inner self. You kept me going, whip by whip, stone by stone, giving me relentless momentum, illuminating the mallet under life's torches and teaching me how to carve myself.

To my family, for unconditional support and attentive hearing, especially to my mother, Diana, my father, Francisco, and my grandparents, Alda and Sotero.

To my supervisors, Professor Doctor Clara Vasconcelos and Professor Doctor Tiago Ribeiro, for their guidance and trust in the work.

To all professors, educators and experts for lucid discussions, sparking the curiosity torch.

To master's colleagues, for being supportive of one another.

To those who share joy and enlightenment in the most casual moments, the most important ones. You give life meaning.

Thank you.

Resumo

A desinformação é uma ameaça para a saúde pública, a democracia e a ciência. A desinformação sobre as alterações climáticas é abundante, especialmente nas redes sociais. A temperatura média da superfície terrestre é expectável que, sem mais ação climática, aumente em 2,6°C até 2100 comparando com os registos pré-industriais. Um grupo organizado formado por produtores de combustíveis fósseis e indústrias, conhecido por máquina da negação, uniu esforços para espalhar a dúvida acerca da ciência climática. Enquanto os cientistas chegam a um consenso em torno da responsabilidade humana, a negação da ciência perde eficácia nos públicos gerais. A máquina da negação redirecionou o foco da negação da ciência para a negação da ação, que se foca em adiar a ação ao disseminar dúvida acerca da necessidade, urgência e agência humana para responder. A compreensão pública sobre as alterações climáticas e o apoio das políticas climáticas são afetados por décadas de propaganda da máquina da negação. A preocupação pública e a vontade de agir continuam a crescer, mas as mudanças comportamentais são insuficientes – Portugal é um exemplo claro disso. A desinformação corrói o suporte público das políticas e da ação. A negação da ciência tem recebido mais atenção pelos investigadores. Isso deixou a psicologia da negação da ação subestudada, especialmente nos públicos gerais. Além disso, os especialistas Portugueses argumentam que há uma falta de compreensão pública das alterações climáticas, independente das atitudes. Os inquéritos públicos têm simplificado a negação das alterações climáticas, subestimando a sua presença no público geral e sobrestimando o conhecimento devido a instrumentos inconsistentes e métodos pouco rigorosos. Os inquéritos falham em providenciar uma metodologia rigorosa para quantificar negacionistas da ação. Através de uma amostra de conveniência foram recolhidos dados quantitativos e qualitativos de 562 participantes. O instrumento consiste num inquérito por questionário que integra uma escala da negação da ação, proposta nesta investigação, e outras escalas previamente validadas para estudar a população geral. Adicionalmente, o instrumento comporta duas questões abertas para avaliar a compreensão pública da ação climática e da ciência climática. As interações psicológicas entre a negação da ação e outras atitudes serviram para assegurar a validade interna do instrumento. Os dados qualitativos receberam um tratamento especial, convertendo classificações nominais de avaliação para formas numerais. Passos adicionais fornecem pistas acerca do efeito do conhecimento na presença psicológica da negação da ação e outras atitudes. A análise fatorial melhorou as escalas, nomeadamente a captura interna das componentes principais (59,4%) e a

consistência interna dos fatores. Resultando na versão final com quatro fatores e 22 itens. Este público geral português demonstra atitudes favoráveis em relação às alterações climáticas. A negação da ação reduz quando as crenças do consenso científico e a consciência das alterações climáticas são superiores, mas aumenta com consciência da ciência climática, o que é consistente com os negacionistas da ação sabermos que a culpabilidade humana é *irrefutável*. A análise sociodemográfica mostrou que a negação da ação é maior à direita na política – em concordância com trabalhos da negação da ciência. Uma metodologia composta por dois métodos de avaliar perfis (*profiling*) através de dados psicométricos respondeu a uma carência da investigação em quantificar adequadamente os negacionistas. Os métodos estimam os negadores da ação entre 15,3% e 19,0% da amostra total ($n = 562$). Os negacionistas da ação estão conscientes da ciência climática, porém, menos demovidos psicologicamente para as crenças do consenso científico e a consciência das alterações climáticas. Estes resultados foram consistentes com análises antecedentes, suportando a idoneidade da metodologia. A avaliação da compreensão pública sugere um défice de conhecimento. A frequência hegemónica de um número reduzido de descritores relacionados com os resíduos (na ação) e com a poluição (nas causas), verificam o efeito da resposta de fuga. Muitos participantes (28,3%) possuíam pelo menos uma de dezassete conceções científicas alternativas, por exemplo, o buraco da camada do ozono contribui para o aumento da temperatura. Uma abordagem de triangulação de métodos enfatiza uma compreensão inferior entre negacionistas da ação. Também, a compreensão prevê atitudes mais positivas. A psicologia da negação da ação tem, aqui, um escrutínio aprofundado resultando num instrumento granular para avaliar a presença da negação da ação nos públicos gerais. A metodologia de *profiling* pode ser aplicada em dados psicométricos quantitativos além da negação da ação. As questões abertas retiram evidência que suporta a sobreestimação da compreensão pública nos inquéritos. Estas e outras contribuições respondem a lacunas críticas na investigação da psicologia por detrás da desinformação. Algoritmos ajustam as redes sociais alimentando falsas expectativas acerca das interações pessoais. Em Portugal, as redes sociais são a escolha das pessoas quando procuram conteúdo científico. Investigar a influência dos algoritmos e das redes sociais na desinformação sobre as alterações climáticas pode alavancar a apatia climática. No final, um quadro-referência cognitivo apresenta uma compreensão abrangente dos motivadores entrelaçados por detrás da desinformação climática nos públicos gerais. Acima de tudo, a dissertação sublinha que o negacionismo climático é ubíquo, não exclusivo aos discursos dos políticos ou às campanhas das indústrias mas está presente na cotidiano nas narrativas internas que justificam a inação ou durante as relações interpessoais que atrasam a transformação comportamental.

Muitas pessoas são *de facto* operadores de um grupo mais contagiante, a máquina da negação da ação.

Palavras-chave: Alterações Climáticas Antropogénicas, Desinformação, Negação da Ciência, Negação da Ação, Compreensão Pública da Ciência, Atitudes, Psicologia Ambiental, Resposta de Fuga, Modelo Cognitivo Não-Linear, Redes Sociais, Inteligência Artificial.

Abstract

Misinformation is a threat to public health, democracy and science. Climate change misinformation is abundant, especially on social media platforms. Global average surface temperature is expected to increase by 2.6°C until 2100, compared to pre-industrial records, without further climate action. An organized group formed by fossil fuels producers and industries, known as denial machine, united efforts to cast doubt on climate science. As scientists reached a consensus around human accountability, science denial loses effectiveness across general audiences. Denial machine redirected focus from science denial to action denial that is postponing action by disseminating doubt about the need, urgency and human agency to respond. Public understanding about climate change and public support for climate policies have been affected by decades of propaganda from the denial machine. Public concern and willingness to act keep growing but behavioral changes remain insufficient – Portugal is a clear example. Misinformation erodes public support for policies and action. Science denial has received most of the attention from researchers. That has left psychology behind action denial understudied, especially in general audiences. Moreover, Portuguese experts argue that there is a lack of public understanding of climate change, independent from attitudes. Public surveys have oversimplified climate change denial, underestimating its presence among general audiences and overestimating knowledge due to inconsistent instruments and unreliable methods. Surveys fall short in providing a stringent methodology for quantifying action deniers. Under a convenience sample, quantitative and qualitative data were collected from 562 participants. Instrument consists of a survey encompassing an action denial scale, conceived in this investigation, and other scales previously validated for general audiences. Additionally, instrument carried out two open-ended questions to test public understanding of climate action and climate science. Psychological interplay between action denial and other attitudes served to secure instrument's internal validity. Qualitative data received special treatment by converting nominal classifications into numerical forms. Additional steps provide insights about effects of knowledge on the psychological presence of action denial and other attitudes. Factorial analysis enhanced scales, specifically internal capture of the principal components (59.4%) and internal consistency. Resulting in a final version with four factors and 22 items. This Portuguese general audience demonstrated favorable attitudes toward climate change. Action denial lowers when scientific consensus beliefs and climate change awareness are superior, but increases when awareness of climate science is higher, which is consistent with action deniers acknowledging that climate

science is *irrefutable*. Sociodemographic analysis showed that action denial is greater on the political right – in line with science denial works. A methodology composed of two methods for evaluating profiles with psychometric data addressed a critical research deficiency of quantifying deniers adequately. Methods estimate action deniers between 15.4% and 19.0% of the total sample ($n = 562$). Action deniers are aware of climate science, however, they are less psychologically moved by scientific consensus beliefs and climate change awareness. These results are consistent with previous analyses, thus supporting methodological adequacy. Evaluating understanding of this general audience suggests a knowledge deficit. The hegemonic frequency of a selected number of descriptors related to waste (on action) and pollution (on causes) verifies the gateway response effect. Many participants (28.3%) expressed at least one of seventeen scientific misconceptions, e.g., the hole in ozone layer contributes to temperature increase. A mixed-methods approach highlights lower understanding among action deniers. Also, understanding predicts more positive attitudes. Here, action denial psychology gets an in-depth scrutiny, yielding a granular instrument for assessing action denial in general audiences. Profiling methodology can be applied to other quantitative psychometric data, beyond action denial. Open-ended questions draw supportive evidence of overestimating public understanding in polls. These and other contributions address critical research gaps in psychology behind misinformation. Social networks structured by algorithms feed false expectations about personal interactions. In Portugal, social media is people's choice when searching for scientific content. Investigating algorithms and social media influence on climate change misinformation can elevate climate apathy. In the finale, a cognitive framework renders an overarching comprehension of underpinnings behind climate misinformation in general audiences. Above all, thesis underscores that climate denialism is ubiquitous, not exclusive to politicians' discourses or industries' campaigns but present in everyday life during internal narratives that justify inaction or during interpersonal relations that delay behavioral transformation. Most people are *de facto* operators of a more contagious group, the action denial machine.

Keywords: Anthropogenic Climate Change, Misinformation, Science Denial, Action Denial, Public Understanding of Science, Attitudes, Environmental Psychology, Gateway Response Effect, Cognitive Tipping Model, Social Media, Artificial Intelligence (AI).

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List of Abbreviations

UN	UNITED NATIONS
UNFCCC	UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE
UNEP	UNITED NATIONS ENVIRONMENT PROGRAMME
IPCC	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
SDGs	SUSTAINABLE DEVELOPMENT GOALS
SDG-13	SUSTAINABLE DEVELOPMENT GOAL 13
O _n	OBJECTIVES
ACC	ANTHROPOGENIC CLIMATE CHANGE
GHGs	GREENHOUSE GASES
GWP	GLOBAL WARMING POTENTIAL
USA	UNITED STATES OF AMERICA
EU	EUROPEAN UNION
IMO	INTERNATIONAL METEOROLOGICAL ORGANIZATION
WMO	WORLD METEOROLOGICAL ORGANIZATION
AR1	ASSESSMENT REPORT 1
AR6	ASSESSMENT REPORT 6
CI	CONFIDENCE INTERVAL
PNAC	NATIONAL PROGRAMME FOR CLIMATE CHANGE
ENAAAC	NATIONAL STRATEGY FOR ADAPTATION TO CLIMATE CHANGE
QEPiC	STRATEGIC FRAMEWORK FOR CLIMATE POLICY
G20	GROUP OF TWENTY
PT	PORTUGAL
WHO	WORLD HEALTH ORGANIZATION
OECD	ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
EDMO	EUROPEAN DIGITAL MEDIA OBSERVATORY
CAPES	COMPUTER ASSISTED RECOGNITION OF DENIAL AND SKEPTICISM
GenAI	GENERATIVE ARTIFICIAL INTELLIGENCE
SPSS	STATISTICAL PACKAGE FOR SOCIAL SCIENCES
RQ _n	RESEARCH QUESTIONS
H ₀	NULL HYPOTHESIS
AD	ACTION DENIAL

K-S	KOLMOGOROV-SMIRNOV TEST
KMO	KAISER-MEYER-OLKIN
CS	CLIMATE SCIENCE AWARENESS
CC	CLIMATE CHANGE AWARENESS
SCA	SUPPORT FOR CLIMATE ACTION
SCB	SCIENTIFIC CONSENSUS BELIEFS
S	SENSITIVITY
CFCs	CHLOROFLUOROCARBONS

Introduction

Human well-being improved across multiple socioeconomic indicators at the cost of tremendous impacts on Earth life-supporting systems (Steffen et al., 2011; 2015a). Anthropogenic systems forced six out of nine Planetary Boundaries (Richardson et al., 2023; Rockström et al., 2009; Steffen et al., 2015b), pushing Earth system into uncharted conditions (Rockström et al., 2024a; 2024b). Two of those overshoot Planetary Boundaries, biosphere integrity and climate, profoundly mediate human activities while ensuring Earth system balance across multitudinous scales (Richardson et al., 2023; Rockström et al., 2024a; 2024b). Earth system dynamics are at risk. Human prosperity, likewise. Here, we answer the call to cease damage with a special focus on climate change.

International attention towards climate change ramped up (Flynn et al., 2024; Ripple et al., 2022; Rockström et al., 2024a) as the risk for inducing irreversible tipping points escalated (Armstrong McKay et al., 2022; Lenton et al., 2008; 2023). United Nations (UN) proclaims conventions and finance programmes, e.g., the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Environment Programme (UNEP). UN meetings and deals have been decisive in creating momentum for climate mitigation. Paris Agreement, proposed in 2015, was later ratified by 195 parties committed, among other objectives, to maintain temperature ideally below 1.5°C or well-below 2.0°C by 2100, compared to pre-industrial average temperature (UN, 2015a; UNFCCC, 2025a). Intergovernmental Panel on Climate Change (IPCC) models predict that mean surface temperatures will very likely (meaning a Confidence Interval range of 90-100%) rise between 2.2-3.5°C if current behaviors and policies persist (IPCC, 2023), so exceeding Paris Agreement goals.

UN conceived Sustainable Development Goals (SDGs) to guide development across economic, social, and environmental indicators (UN, 2015b). Lately, UN evaluated those 17 goals, reporting that only 17% of SDGs are on a trajectory for fulfilling initial pledges, 48% demonstrated minimal or moderate progress, and an alarming 35% are regressing (UN, 2024). Climate action, Sustainable Development Goal 13 (SDG-13), shows limited progress across indicators (UN, 2024).

Climate change is already affecting populations worldwide (IPCC, 2023; Ripple et al., 2022). If action is ignored, climate change will impact future generations (Armstrong McKay et al., 2022; IPCC, 2023; Ripple et al., 2022). Thereon, addressing climate change represents an interspecies, intra- and intergenerational ethical duty (Gupta et al., 2024). Pace and scale of climate action fall short in meeting the requirements to undergird a safe and just future (Future Earth et al., 2024; Gupta et al., 2024; IPCC, 2023; Richardson et al., 2023).

Fortunately, citizens' engagement reveals key opportunities for making dramatic changes (Gupta et al., 2024; Powell et al., 2023; Richardson et al., 2023; Sachs et al., 2019). Then, what factors are obstructing citizens from adopting climate-friendly habits?

A myriad of factors ascribe those conditions. Misinformation is almost everywhere (Lewandowsky et al., 2017), and its effect on people's beliefs must not be ignored (Cook, 2020; Ecker et al., 2024; Lewandowsky et al., 2016; van der Linden et al., 2017). Misinformation perniciously erodes individuals' trust in institutions, including the scientific enterprise, while challenging democracies and causing harm (Cologna et al., 2024; 2025; Ecker et al., 2024). Various stakeholders hide vested interests behind misinformation campaigns that aim to defy climate science and/or disprove the need, urgency and human agency to act, known as science denial and action denial, respectively (Capstick & Pidgeon, 2014; Cook, 2020; Damico et al., 2023; Fasce et al., 2023; Kutney, 2024; Lamb et al., 2020; Supran & Oreskes, 2021). Those campaigns run under multiple platforms (Cook, 2020; Dunlap et al., 2016; McCright et al., 2016; Oreskes & Conway, 2010); their fallacious allegations amplify doubt through various rhetorical strategies, ultimately altering trust and involvement once hatched in the nest of public perception. Climate change denial influences intergroup norms and values while dictating beliefs, for instance, recognizing scientific consensus and supporting mitigation policies (Lewandowsky, 2021; Lewandowsky et al., 2013; 2016; Schmid & Betsch, 2019).

Science communication and education can foster positive attitudes toward science and contemporary challenges (Bauer & Falade, 2021; Bodmer, 1985; Bowater & Yeoman, 2013; Cologna et al., 2024; 2025; Miller, 2004), in this case, about climate science and climate change consequences (Cologna et al., 2024; Cook et al., 2017; Hart & Nisbet, 2012; Kutney, 2024; Maertens et al., 2025; Ranney & Clark, 2016; Schmid & Betsch, 2019; van der Linden et al., 2017). Evidence of a growing concern alongside low citizen involvement steers discussions on science communication and education practice and investment, and reliability of research instruments to capture trustworthy data on psychological constructs (Bauer & Falade, 2021; Flynn et al., 2024; Mendy et al., 2024; Ranney & Clark, 2016; van der Linden et al., 2017). Action denial is particularly understudied (Cook, 2020; Damico et al., 2023), so its implications continue unexplored.

Thereby, thesis sheds light on action denial psychology (advancing a novel factor) and climate-related beliefs (based on previously valid scales) while evaluating understanding of climate action and science essentials. To do so, research objectives (O_n) were defined.

(O_1) To build a valid psychometric instrument for quantifying action denial psychological construct among a Portuguese population.

- (O₂) To assess some of their attitudes towards climate change.
- (O₃) To study other attitudes influence on action denial psychological presence.
- (O₄) To analyze sociodemographic prevalence in action denial and other climate change attitudes.
- (O₅) To quantify action deniers.
- (O₆) To evaluate understanding of climate action and climate science essentials.
- (O₇) To study level of understanding influence on action denial psychological presence.

These objectives capture the research goal of delving into the public conversation around climate change, full of pernicious side agendas masking vested interests behind denial discourse curtains.

This final part of the introduction outlines the structure of the thesis. Upcoming subsections review the state of play of fundamental concepts, including [anthropogenic climate change](#), [milestones in climate science and policy](#), [attitudes toward climate change](#), [overview of Portuguese behaviors, attitudes and understanding](#), and [misinformation and climate change denial](#). Followed by [methods](#) that provides stepwise descriptions of all methodological steps, including [research questions](#), [research design and sampling](#), [participants](#), [instrument and variables](#), and [procedure](#) itself. Then, the reader can find [results](#) drawn from [exploring action denial psychological construct](#), [assessing attitudes toward climate change and action denial](#), [quantifying action deniers](#), and shedding further light on [the interplay between understanding and action denial](#). [Discussion](#) joins outputs from crucial results. Then, [thesis significance](#), [holistic perspective and insights for future research](#) extract the most valuable research endings. By the time [conclusions](#) have appeared, the reader can expect to be fully familiarized with all the work.

1. Sneaking into action denial plot

The contrarian play was on exhibition in the nearest theaters. The word spreads quickly, thus securing enough tickets was a hard task. D-day came; getting there early created time for roaming around the theater entrance. After an initial recognition, their backstage conversation whispers struck our curiosity. Arriving early created the perfect opportunity to sneak into the backstage just before they setting up the scenario. Distant noises guided a furtive approach to the backstage. What was conversation about behind that curtain? That is what the reader will find out shortly.

1.1. Anthropogenic climate change

Anthropogenic climate change (ACC) is an umbrella concept grounded by climate science premises and the social conversation around it (Lewandowsky et al., 2016; Lynas et al., 2021; McCright et al., 2016; Oreskes, 2004). ACC encompasses scientific consensus notions, climate action and climate science essentials that implicitly extend the discussion to its underlying causes and consequences. Central concepts in the public conversation around climate change. That is why this investigation examined climate change knowledge and scientific consensus beliefs. But first, stage lighting sheds upon (1) climate science essentials before spotlighting (2) scientific consensus and (3) causes and consequences.

1.1.1. Climate science essentials

Humans benefited from a stable climate for 11,700 years (Kaufman et al., 2020), the Holocene epoch. Holocene conditions were optimal for the rising of contemporary civilizations (Rockström et al., 2009; Steffen, 2011; 2015a). Nonetheless, climate variability on a geological time scale has produced long-term changes in the entire Earth system (Crutzen, 2002; Kaufman et al., 2020). Paleoclimatic models are useful comparative tools for assessing ongoing human impact (Crutzen, 2002; Jansen et al., 2007; Kaufman et al., 2020; Masson-Delmotte et al., 2013). When compared to **pre-industrial temperature** records, they show that human activities have disturbed the climate (IPCC, 2023; Kaufman et al., 2020; Richardson et al., 2023), pushing temperature outside Holocene average of 14.0°C (Osman et al., 2021).

All sorts of daily activities emit greenhouse gases (GHGs) directly and/or indirectly (along the supply chain), thus contributing to the greenhouse effect responsible for global warming (Chen et al., 2021; Eyring et al., 2021; IPCC, 1990; 2023; Richardson et al., 2023; Steffen et al., 2011; 2015). Climate stability relies on the **greenhouse effect** to maintain temperature ranges within biologically habitable boundaries, but even slight alterations in atmospheric composition can amplify the greenhouse effect to unbearable climate

conditions (Eyring et al., 2021; IPCC, 1990; 2023; Steffen et al., 2011; 2015). What does the greenhouse effect consist of? Infrared light (less energetic radiation with wide wavelengths) acquires different wavelengths after reflecting off Earth's surface. Vectorial directions tilt toward outer space, eventually escaping or getting trapped when physically and chemically interacting with GHGs. While GHGs concentrations bulk up, less infrared light escapes from Earth and gets trapped back into the atmosphere, warming it (IPCC, 1990).

Pre-industrial estimations of **average surface temperature** and GHGs concentrations serve as reference values for comparison with contemporary observations. Pre-industrial records (1850-1900) estimate reference values for temperature at $14.0 \pm 0.5^{\circ}\text{C}$ and carbon dioxide (CO_2) concentration at 280 parts per million (ppm), Holocene-like conditions (Kaufman et al., 2020; Rockström et al., 2009). Since then, about 2400 ± 240 gigatons of CO_2 have been pumped into the atmosphere (IPCC, 2023). High confidence estimations assign a 1.1°C warming (at 410 ppm) between 2011-2020 compared to pre-industrial reference values (IPCC, 2023). Updated 2023 data estimate an increase of about 1.3°C in global average temperature, although Europe reached a 2.3°C warming (Copernicus Climate Change Service, 2025).

Consecutive years of record mean temperatures within an unprecedented rate of change for past decades are consistent with CO_2 unrecorded concentrations for the last two million years (IPCC, 2023; Ripple et al., 2022). Abrupt rate of change violates genetic and evolutionary adaptation paces (IPCC, 2023). Humans altered Earth system pristine conditions (Rockström et al., 2009), leading to the proposal of **Anthropocene**, a new geological epoch (Crutzen, 2002; Steffen et al., 2011; 2015a). Besides, formally dismissed by the International Union of Geological Sciences (2024), Anthropocene concept still makes sense of human planetary-scale impact. Above all, humanity needs to redefine its relationship with nature (Santos, 2021). Climate change consequences figure among the most challenging threats to Humanity, calling for immediate action to safeguard Planetary Commons – valuable natural assets only available if Earth system remains stable (Ripple et al., 2022; Rockström et al., 2024b; World Economic Forum, 2024).

Climate change evolves outside linear trends, thus demanding constant improvements in models and sensors. Specific GHGs possess a defined **global warming potential** (GWP). Different molecular compositions, arrangements and lifespans grant these gases differentiated radioactive forcing effects – phenomena known for warming or cooling atmospheric layers through energy transferences (Ramaswamy et al., 2018). GWP is compared by converting all GHGs into carbon dioxide equivalent ($\text{CO}_{2\text{-eq}}$) assuming a 100-

year lifespan. The main GHGs, atmospheric concentrations and GWP are CO₂ at 427 ppm with 1 of GWP, methane (CH₄) estimated at 1929 parts per billion (ppb) and 27.2-29.8 GWP, and nitrous oxide (NO₂) registering 332 ppb and 273 GWP (Chen et al., 2021; IPCC, 2023; National Aeronautics and Space Administration, 2025).

A glance at climate science essentials underscores climate science complexity. Indeed, ACC is a wicked problem (Incropera, 2015; Rittel & Webber, 1973) demanding transdisciplinary comprehension of interwoven subsystems and their intricate relations and causalities (Chen et al., 2021). There are reasonable expectations that lay people struggle to understand it. Complexity also explains why misinformation dilutes in public perceptions so easily (Cook et al., 2016; Lewandowsky et al., 2020; McCright et al., 2016; Nisbet, 2014; Oreskes & Conway, 2010; Ranney & Clark, 2016; Yearley, 2021). Climate action does not necessitate the public to master climate science, however, key concepts and reasoning skills are life-saving instructions in a fast-paced changing world.

1.1.2. Scientific consensus

Scientists reached a **99% consensus on human accountability for climate change** (Cook et al., 2016; Lynas et al., 2021; Oreskes, 2004). While many IPCC experts agree that climate change is a global crisis (Tolleson, 2021). The public, however, is less unanimous on those matters; from a Portuguese sample ($n = 506$), 85.6% perceive scientists' consensus and 84.3% see ACC as a global crisis. Still, higher than the average from 27 countries of 84.9% and 83.9% with a broad sample of $N = 10,527$ (Večkalov et al., 2024). Hence, scientific consensus beliefs are an important part of climate change psychology.

Denial claims are known for carrying false allegations toward scientific consensus, trying to erode public trust in scientific institutions (Weber & Stern, 2011). Scholars caught deniers' scripts ideated by the tobacco industry long ago (Oreskes & Conway, 2010), attempting to cast doubt upon the scientific consensus (Cook, 2020; Cook et al., 2016; Lewandowsky et al., 2013). Usually, climate scientific consensus is attacked by misleading frames of uncertainty (an intrinsic characteristic of the nature of science), creating confusion about GHGs (e.g., aerosols negative radioactive forcing), misinforming about human accountability and/or defying the existing consensus itself (Farrell, 2016; Weber & Stern, 2011).

Scientific consensus messages can improve general audiences' acceptability of human responsibility and support for policy (Lewandowsky et al., 2013; 2017; Ranney & Clark, 2016). Scientists warn about a planetary climate emergency (Future Earth et al., 2024; Ripple et al., 2022). Advocacy can enhance public trust in science without compromising scientists' credibility (Cologna et al., 2024; 2025). Thus, experts are encouraged to engage

with diversified audiences in advocating for climate action. Science communicators and educators are central actors in preluding their voices into the public conversation around climate change (Cook, 2020; Damico et al., 2023; Kutney, 2024; La et al., 2024; Lewandowsky et al., 2013; McCright et al., 2016; Mendy et al., 2024; Ranney & Clark, 2016; van der Linden et al., 2017).

1.1.3. Causes and consequences

Although climate change causes and consequences seem always to flow into tautological activities related to emissions, making almost any attempt to be valid. Understanding underpins more than a list of activities. Understanding them calls for systems thinking, or mechanistic knowledge, following Ranney & Clark (2016). Their comprehension indirectly synthesizes sectors where human activities can decarbonize.

Causes by **sectors** are electricity and heat production, transportation, agriculture, manufacturing and construction, industry, buildings, waste, land use, and shipping and aviation (Ritchie et al., 2020; UNEP, 2024). Climate system links to all biophysical systems with implications on several of them (Rockström et al., 2024b); ACC exacerbates biodiversity loss and ecosystem resilience, extreme weather events frequency, migration and conflict, food insecurity, wildfires, thaw, health risk factors, and infrastructure damage with hazards become more frequent and severe (IPCC, 2021).

Among the most prolific climate change denial discourse features gaslighting around causes and consequences (Biddlestone et al., 2022; Farrell, 2016). Additionally, science communication and climate education underinvestments explain low understanding and misinformation persisting (Cook, 2020; Ecker et al., 2022; Kutney, 2024). There is a need to clarify oversimplifications of climate science at the core of people's misrepresentations.

One of the most common attacks emerges from climatic cyclicness (Farrell, 2016); Milankovitch cycles are oversimplified to divert human responsibility to orbital cycles consisting of multiple vectorial direction tilts in Earth's orbital axis that alter insolation and therefore the climate (Berger & Loutre, 1991; Jansen et al., 2007; Masson-Delmotte et al., 2013). Physical, chemical and biological data support historical climate oscillations (IPCC, 2023; Jansen et al., 2007; Masson-Delmotte et al., 2013). Whenever treated carefully, those premises contradict any claim trying to divert attention from humans to natural causes. Milankovitch cycles take thousands of years to produce measurable change. How could they cause any measurable decadal oscillation? And so, how do they explain yearly variation observations?

Other allegations try to counter climate science by **disaligning scientific content** without caring for evidence. For instance, *supported* by solar variability and El Niño and La Niña concepts. Solar radiation variability radiometric records, including for infrared waves, do not contribute significantly to ACC (Lockwood, 2008). Scientific discussion around ocean circulatory patterns heated up recently. El Niño and La Niña describe cyclical circulatory patterns of air and ocean water in the Pacific Ocean Basin with dichotomous outcomes; El Niño warms and La Niña has a cooling effect, both may interfere with global climate (Eyring et al., 2021). Often, deniers use these natural phenomena, El Niño and La Niña, to divert attention from human accounting by oversimplifying them and overstating their influence. Despite possible effect, studies on factual contribution to recent change remain inconclusive (Armstrong McKay et al., 2022; Eyring et al., 2021). These are just two examples denoted in the climate change denial scripts. Many misleading narratives about climate change causes and consequences undermine public trust in science.

1.1.4. Anthropogenic climate change at a glance

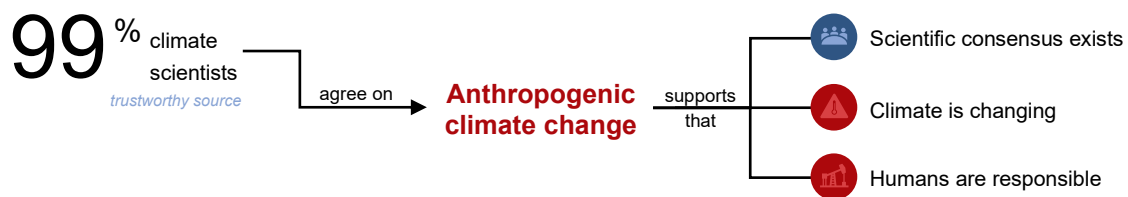


Figure 1. Schematic summary of Anthropogenic climate change sub-section.

1.2. Milestones in climate science and policy

Economic stability depends on climatic stability (Stern, 2007), so climate change should be a common concern to scientists, politicians, decision-makers, entrepreneurs, businessmen, and citizens. Historical events emerged from specific landmarks, and mentioning them is valuable for framing this research. The brightest stages where climate science actors and climate policy actors performed still echo relevant pieces. Below, they are present as the (1) international and (2) national milestones tapes are rewound.

1.2.1. International milestones

Economies and social stability depend on a stable environment with a well-functioning provisioning natural system (IPCC, 2023). Thus, efforts in climate change mitigation are non-negotiable to safeguard Planetary Commons (Ripple et al., 2022; Rockström et al., 2024b), where intra- and interspecies and intergenerational justice enter (Gupta et al., 2024). But when did scientists and policymakers become aware of the climate emergency? And how?

Hardly sociocultural movements gained as much attention in a narrow period as the environmental movements did. The first World Environment Day was celebrated on 5 June 1972. UN held an extensive repertoire of various awareness-promoting meetings; those standing out in the crowd about climate matters served diligent scientific and political reforms. In the same year, the **United Nations Conference on the Human Environment**, coined as the Stockholm Conference, transformed environmental agendas (UN, 2025a). Concurrently, **The Limits to Growth** was published by the Club of Rome in 1972, drawing attention to global economic dependence on resources (Meadows et al., 1972).

Later in 1987, Gro Harlem Brundtland (1939-) coordinated one of the most valuable reports ever made, the World Commission on Environment and Development report, also known as Our Common Future, which insisted that chasing exponential capital growth could not sustain long-term development. World Commission on Environment and Development reformed development indicators by defining **sustainable development**, proposing that present generations should satisfy their needs without exhausting or compromising future generations' ability to progress and meet their needs too (United Nations Secretary-General & World Commission on Environment and Development, 1987). These values prevail in research and policy since then, including in the most promising sustainability theory frameworks, e.g., Planetary Boundaries (Steffen et al., 2015), Earth System Boundaries (Gupta et al., 2023), Planetary Commons (Rockström et al., 2024b).

UN has been reiterating its position ever since through various meetings and supranational bodies; **Earth Summit** celebrated 20 years in Rio de Janeiro, Brazil, in 1992, since the Stockholm Conference. Rio Conference still holds global influence over politics and science. Scientists, politicians, and stakeholders discussed climate change, biodiversity loss, and other environmental problems (UN, 2025b). Among Rio's Conference cornucopious outputs feature declarations, frameworks, and worldviews, including *think globally and act locally* view has been taught and spread everywhere.

United Nations Framework Convention on Climate Change (UNFCCC) itself was established in Rio de Janeiro (UN, 2025b). UNFCCC is a supranational entity with non-regulatory but meaningful influence in national policy and paramount contributions to GHGs inventories (UN, 2025b; UNFCCC, 2025b). UNFCCC held the first **Conference of the Parties** (COP) in 1995 (UNFCCC, 2025c), gathering international and cross-sectoral decision-makers and stakeholders to broaden the discussion around climate change. COP meetings have occurred annually since then. These meetings are stages of the most important milestones, specifically the Kyoto Protocol (COP3) and the Paris Agreement (COP21).

Without an observable reduction in GHGs, the **Kyoto Protocol** (1997) proposed trading mechanisms for tackling climate change responsibility imbalances during COP3 (UNFCCC, 2025d). Trading mechanisms emerged from the polluter pays principle by capitalizing and taxing fair shares of emissions. Nations (or parties) could trade carbon dividends between them; parties with less carbon-intensive economies would sell their carbon surplus to those with carbon debts that bought carbon credits to cover excessive emissions.

United States of America (USA) is a mass emitter and one of the most famous stages where climate denial features. Climate change became a politicized topic early on in USA. When President George H. W. Bush (1946-) withdrew USA from the Kyoto Protocol, he contributed to climate change scepticism politicization (Cook, 2017; Farrell, 2016; McCright & Dunlap, 2000).

During COP21, in 2015, France, endovers intensified with the **Paris Agreement** creating decisive momentum for climate action by getting 196 parties' commitment to limit global warming (UNFCCC, 2025a). Countries amended their constitutions and legislation to ensure that temperature increase would not exceed 1.5-2°C until 2100 (UN, 2015a; UNFCCC, 2025a).

In 2015, Sustainable Development Goals (SDGs) set 17 key goals to enhance Our Common Future to be delivered by 2030 (United Nations Department of Economic and Social Affairs, 2025). SDGs succeeded Millennium Development Goals after global challenges remained unresolved. SDG-13 calls everyone to join eco-friendly behaviors (United Nations Department of Economic and Social Affairs, 2025). Climate change mitigation would benefit from progress in any SDG due to climate-human-biodiversity interconnectedness.

Donald Trump (1946-) government withdrew USA from Paris Agreement in 2017 (Canon et al., 2025). Associating their resignation with their tremendous economic and societal influence over Western cultures created an optimal environment for spreading climate change denial. Joe Biden (1942-) rejoined the Paris Agreement in 2021 (UNFCCC, 2021). Still, shortly after Trump regained the Presidency in recent elections, his administration, again, withdrew Paris Agreement (Canon et al., 2025).

Meanwhile, the European Union (EU) stood at the vanguard of climate action; the European Commission and the European Parliament are devoted to achieving carbon neutrality by 2050 (European Commission, 2025a). The EU exerts normative power over national policies, so nations have an embargo period to align their goals with EU interests through political, legislative, fiscal, and judiciary power reforms in light of the European Green Deal and European Climate Law. Both are part of a long-term integrated strategy to phase out

fossil fuels and embrace renewable energy power plants while conserving nature, provisioning systems and cultural heritage (European Commission, 2025b; 2025c).

All these governance-related events evolved in parallel with climate science development. International Meteorological Organization (IMO) was created in 1873 and later subsumed into the **World Meteorological Organization** (WMO), an international body running under UN auspices since its birth date in 1951 (WMO, 2025). The first World Climate Conference occurred in Geneva (WMO, 1979), joining most prominent scientists, including those of WMO, to discuss their perspectives and insights about climate science.

Early data suggesting human accountability led WMO and UN Environment Programme, with support from the UN General Assembly, to establish the **Intergovernmental Panel on Climate Change** (IPCC) in 1988 (IPCC, 2025). IPCC is the ongoing leading expert group on climate science. Two years later, IPCC's first assessment report (AR1) systematized fundamental concepts of climate science (IPCC, 1990). IPCC working groups produced six overarching assessment reports on climate science (1990, 1995, 2001, 2007, 2014, and 2023). Reports systematically reviewed the latest science guiding politicians and decision-makers worldwide.

IPCC's latest report was published in 2023 by the Cambridge University Press. Assessment Report 6 (AR6) stressed that carrying on without behavioral and political change will very likely, referring to a Confidence Interval (CI) higher than 67%, lead to an increase of 2.6°C in global average surface temperature by 2100 (IPCC, 2023). Along this current trajectory, Earth system stability will face aggravated cascading effects by crossing climate tipping points (Armstrong McKay et al., 2021; Lenton et al., 2023), pressuring even more biophysical limits (Gupta et al., 2024; Richardson et al., 2023).

1.2.2. Portugal milestones

International agendas set targets that require nations to amend legislation, Portugal is no exception. Policy reforms have been trying to enhance environmental quality, reduce emissions and biophysical pressure on natural resources.

Portugal stood at the forefront of European countries in environmental law by promulgating the Basic Environmental Act early in 1987 (see Diário da República no. 81/1987). On the other hand, Kyoto's Protocol commitments were embraced too late in Portugal due to institutional and corporate discredit in carbon trading schemes (Carvalho et al., 2013). In the absence of climate bodies, in 1998, the Inter-ministerial Commission on Climate Change was launched, the first governmental body with superintending authority over national policy on climate matters (Carvalho et al., 2013).

Portugal introduced the **National Programme for Climate Change** (PNAC in Portuguese) in 2001. Nevertheless, Kyoto's objectives to reduce emissions remained unaddressed even when Executive Committee for the Climate Change Commission started coordinating climate policy in 2006. PNAC was part of the National Strategy for Climate Change (2001) that simultaneously introduced the National Plan for Allocation of Emissions Allowances (2005) and Portuguese Carbon Fund (2006) (Carvalho et al., 2013; Schmidt & Delicado, 2014), instruments forged under Kyoto's Protocol carbon trading schemes, but their integration and effectiveness still are questionable (Schmidt, 2010).

Early 2010s, with Kyoto's targets getting out of reach and scientists' warnings on climate consequences sounding loud across continents, including in Portugal, the EU kept pressuring to amend climate plans (Santos et al., 2001; Schmidt, 2010). By this time, models projected that heatwave and drought frequencies would increase during estival periods and nearly 800 km of coastal area would be at risk due to sea level rise, while stressing that food production, human health, and biodiversity will also be at risk as temperatures raise (Santos et al., 2001; Schmidt, 2010). So, **National Strategy for Adaptation to Climate Change** (ENAAC in Portuguese) implemented action plans from spatial and territorial planning, water resources management, health, energy, biodiversity, and defending coastlines and contiguous areas (Schmidt & Delicado, 2014; Schmidt, 2010).

Strategic Framework for Climate Policy (QEPiC in Portuguese) released in 2015 fortified Portugal's commitment to Paris Agreement targets by encompassing the National Climate Change Program and the National Strategy for Adaptation, main adjunctive instruments at the service of Portugal's climate policy (Agência Portuguesa do Ambiente, 2015).

National endurance in climate policy relies on their highest representatives attending international meetings, alleviating fiscal burdens to stimulate private investments and incentives for science and technology projects. A Portuguese voluntary report on SDGs progress came out with insufficient data for evaluating SDG-13, particularly climate education and climate change information dissemination progress toward a climate-literate society (República Portuguesa, 2023). However, all legislative plans, QEPiC, PNAC and ENAAC, centralized education and communication about climate change in their core objectives for achieving citizens' support for climate policy and involvement in climate action (Carvalho et al., 2013; Schmidt, 2010).

Along with other EU-members, Portugal amended national constitution according to the European Green Deal and European Climate Law. Moreover, Portugal delivered a national roadmap to carbon neutrality by 2019 (Agência Portuguesa do Ambiente, 2022; EU, 2021), a comprehensive guide to decouple economic reliance on fossil fuels and capitalize

investment in renewable energy power plants. Initial climate neutrality pledge was revised in December 2021 when parliamentary votes passed the Basic Climate Law (EU, 2021; see Diário da República no. 253/2021). In 2023, Portugal drafted and submitted the National Energy and Climate Plan to EU (EU, 2021; see Agência Portuguesa do Ambiente, 2024), focused on meeting EU's 2050 long-term strategy for becoming the first climate-neutral continent.

The political scene in Portugal has been unsettled due to consecutive parliamentary dissolutions and early elections. While governments struggle to agree on other parliamentary decisions, climate change mitigation plans are overlooked and remain attentive only to a finite group of researchers, journalists, and activists. Even so, Portuguese energy production coming from renewable sources is associated with good performance in indicators related to emissions reduction and climate policy, according to the Climate Change Performance Index (Climate Change Performance Index, 2025).

1.2.3. Milestones in climate science and policy at a glance

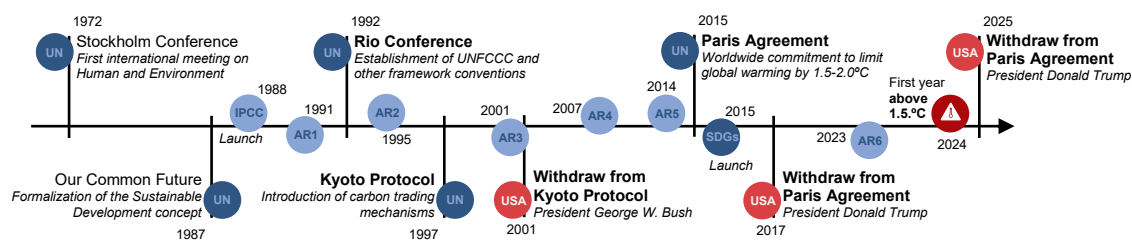


Figure 2. Schematic summary of Milestones in climate science and policy sub-section.

1.3. Attitudes toward climate change

Usually, researchers are the first to identify or even predict problematic situations. Pressure from the scientific community unites policymakers in solving those problems. Only then, citizens get to know their role and join efforts. The reader can notice that sneaking into the action denial scene followed the same steps. After watching what scientists say about ACC and what politicians and decision-makers have decided to do, let us examine what lay people think about climate change. Below, stage lights turn to (1) define attitudes, (2) conceptualize beliefs and perceptions and (3) provide an overview of global beliefs, perceptions and attitudes.

1.3.1. Attitudes concept

Since early inquiries, psychologists strove to understand **attitudes** (Campbell, 1963; Eagly, 1992). And defining them was an important part of the process. Attitudes are fundamental in psychology studies, including environmental psychology, that can be inferred from

individuals' psychological dimensions (cognitive, social, and affective) through favourability, willingness, or agreement in a particular set of dispositions (intentions for action). All dimensions are loaded in a common mental model and operate during decision-making (Dunlap et al., 2002; Ecker et al., 2022; Miller, 2004). So, attitudes can only be observed by weighing all attitude dimensions. Attitudes per se cannot fully predict behaviors, but they are ultimate prescribers of action.

1.3.2. Beliefs and perceptions concepts

Often, characteristics distinguishing **beliefs and perceptions** from attitudes are overlooked. Beliefs and perceptions are less restrictive than attitudes. Although all three can capture how individuals identify and relate to a domain, beliefs and perceptions are not confined to dispositions (Campbell, 1963; Eagly, 1992; Oskamp & Schultz, 2014). Beliefs and perceptions can be measured through closed-ended questions (e.g., multiple-choice), open-ended questions, and interviews (Oskamp & Schultz, 2014). Unlike attitudes that require psychometric scales and dispositional-type formulation instruments (Campbell, 1963; Eagly, 1992). Beliefs showcase what individuals think about a particular subject without ascribing specific behavioral intentions. Perceptions are emergent relations from sensorial-cognitive interpretation of stimuli. Take the following propositions: (1) most individuals believe that climate is changing, (2) people often underestimate others' concern about climate change, despite (3) reports inferring high concern levels and support for climate action. Believing in ACC in a broad sense does not imply action. Carrying the perception of peers' high concern, the same. Endorsing "higher taxes for carbon-intensive products" sets concrete behavioral intentions, i.e., attitudes. Putting all that together, beliefs can be seen as solidified perceptions, and attitudes are the application of beliefs into *action*.

1.3.3. Overview of global beliefs, perceptions and attitudes

Climate change attitudes have been studied across all continents (Mede et al., preprint). The world's largest survey, conducted by UNEP and Oxford researchers, concluded that 80% of individuals want their country to boost climate action, 69% have altered consumption habits influenced by their **high climate concern**, and 53% are more worried about climate implications now than before (Flynn et al., 2024). Alongside concern, researchers tested the public beliefs about fossil fuels, where 72% of people demonstrated **willingness to phase out of fossil fuels** sharply, 86% are willing to cooperate toward climate goals, and 79% of people from wealthy countries want to help populations from low- and middle-income countries (Flynn et al., 2024). More than half of the population from nine out of ten mass oil producers is willing to phase out as quickly as possible. In world-leading economies (the Group of Twenty, known as G20), 84% of individuals **endorse collaborative bounds**

for climate mitigation (Flynn et al., 2024). Extreme weather events are expected to increase (IPCC, 2023); almost half of the global population *perceives* a growing rate in extreme weather events and 78% fear being unprepared for extreme weather scenarios (Flynn et al., 2024).

Before entering Portuguese territory, Eurobarometer data looks at the European population. **EU citizens** are likewise concerned about ACC, whereas 77% see climate change as a serious threat and 67% are concerned about their government plans' inability to address climate consequences. EU citizens' willingness to act is mirrored in multiple self-described actions. Nearly 70% claim to recycle, 53% avoid generating waste, 37% care for energy efficiency appliances, 31% consume less meat, 28% prefer organic food and 28% practice eco-friendly transportation habits (EU, 2023a). Data are self-described behaviors, so should not be taken as third-party observations. Notwithstanding, these self-reported behaviors give information about public willingness to work toward carbon neutrality. Additionally, provide evidence of different courses of action. EU citizens display similar outputs for environmental attitudes (EU, 2024), a broader concept.

The **perception gap** persists, between how the public perceives their peers' concern and willingness to cooperate in climate mitigation (Andre et al., 2024; Geiger & Swim, 2016). Pluralistic ignorance explains why this perception gap downscales citizen involvement in climate action. Whenever people feel that their peers are unmotivated to discuss climate matters or unwilling to participate in climate action, their own willingness drops (Andre et al., 2024; Geiger & Swim, 2016). Shifting social norms and values is necessary for overcoming climate apathy and leveraging behavioral inertia. Combating the perception gap is an important part of the transformation.

1.3.4. Attitudes toward climate change at a glance

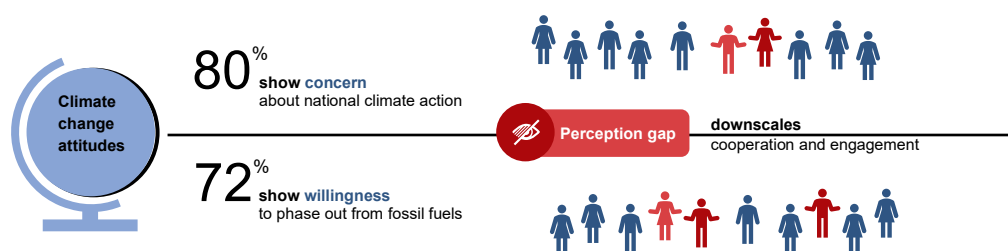


Figure 3. Schematic summary of Attitudes toward climate change sub-section.

1.4. Overview of Portuguese behaviors, attitudes and understanding

Hardly the same play is performed twice in the same way whereas diverse casts have their own peculiarities. Portuguese theaters feature their actors with special skills. Hereafter,

there is portrayed information on (1) Portuguese environmental behaviors, (2) beliefs, perceptions and attitudes, and (3) understanding of climate change.

1.4.1. Portuguese environmental behaviors

Technique consists of self-reported instruments without complement by any direct observation of behaviors then a brief recap of Portugal (PT) environmental behavioral profile justifies thesis relevance.

According to Yale's Environmental Performance Index 2024 data, PT occupies the 26th rank (from a list of 180 countries) with worse performance in ecosystem conservation and climate change mitigation indicators (Block et al., 2024). In 2025, PT drops to the 15th rank, two positions behind 2024 results from the Climate Change Performance Index (Climate Change Performance Index, 2025). These measurements offer valuable overarching views of national efforts in bridging sustainability objectives.

Diving deeper into individual indicators suggests that PT has a long way to go to reach climate goals. While 68% seem devoted to climate action by arguing that they have made intentional efforts in the past six months, 30% have not made any effort to offset their emissions (EU, 2023a).

Energy sector alone was responsible for 68% of GHGs emissions in 2023 (UNEP, 2024); the EU established a reduction target of 11.7% in energy consumption until 2030 (EU, 2023b), which PT have been failing to comply even with investments in renewable sources (Direção-Geral de Energia e Geologia, 2023). Moreover, PT is among the poorest European countries in building energy efficiency (Horta et al., 2019).

Contemporary **food consumption habits** are responsible for 26% of GHGs emissions (Poore & Nemecek, 2018); World Health Organization (WHO) caloric intake recommendations for adults range from 2,000-2,500 kilocalories (kcal) per day (WHO, 2020) while PT average is more than 4,000 kcal (Statistics Portugal, 2021). PT plates excessively filled with meat, fish, and seafood (food with more emissions), leaving little room for fruits and vegetables (food with reduced associated emissions) (Galli et al., 2020). PT's dietary practices are outside guidelines for public health and environmental conservation (Willett et al., 2019).

The European Parliament and the European Council aimed to reuse and recycle at least 55% of municipal **waste** weight in the present year (EU, 2008). Expectations rise that PT will fail to comply again, as 2023 data estimates a rate lower than 31% of municipal waste treated properly within Portuguese borders (EUROSTAT, 2025).

Portuguese economic activities and individual behaviors are responsible for surpassing national **biocapacity** on May 5th this year (Earth Overshoot Day & Global Footprint Network, 2025). PT population consumes more resources than endogenous ecosystems can biophysically generate and upcycle. Thus, PT relies heavily on imports and market provisioning systems to satisfy their high resource demand.

Otherwise, PT shows signs of embracing sustainability. Government promulgated a car circulation restriction in Lisbon, reducing pollution and stimulating low-impact mobility (European Union Urban Mobility Observatory, 2023), as transportation is responsible for most of national emissions (Ritchie & Roser, 2020). The last coal-generating power plant shut down in 2021 (República Portuguesa, 2021). Public funds have been channeled into restoring natural habitats (Fundo Ambiental, 2024). These are just a few examples, more could draw attention to the bright side of climate action in PT.

1.4.2. Portuguese beliefs, perceptions and attitudes

Happens in Portugal, like in other countries, people are saying that they make individual efforts but national statistics picture otherwise while national annual emissions keep growing. That effect is known as action gap.

About 89% of Portuguese respondents envisage climate change as a serious threat, and even more (94%) as a public health issue (EU, 2023a). They perceive poverty, hunger, water scarcity and economic stability as more concerning problems than climate change, however. In another study, 88% of PT population recognizes climate change as the hardest contemporary challenge, with 77% recognizing that it influences their daily lives (European Investment Bank, 2022). All data suggest that PT citizens are **highly concerned** about ACC repercussions (EU, 2023a; European Investment Bank, 2022), including national long-term overviews (Schmidt & Delicado, 2014).

An astonishing 91% would be willing to trade short-distance international flights for efficient trains (European Investment Bank, 2022). **Willingness** to disincentivize public expenditure on fossil fuels by replacing fossil subsidies with investments in renewables appears in 89% respondents. Nevertheless, just 45% support extraordinary climate taxes in their energy bill to accelerate this transition (EU, 2023a), which is inconsistent with European Investment Bank Climate Survey whencein 77% are willing to pay carbon caps in emissions-intensive products and services (European Investment Bank, 2022).

Alternative public beliefs and perceptions can bolster misinformation influence. 82% view inaction as more costly than the green transition (EU, 2023a). 77% understand ACC impact on their daily lives (European Investment Bank, 2022). Most saw opportunities in climate

change mitigation to stimulate innovation and competition across EU companies (86%), improvements from reducing fossil fuel imports (84%), and opportunities in adaptation that could benefit EU citizens (85%) (EU, 2023a).

Nonetheless, PT citizens want governmental authorities to recognize responsibility for climate mitigation, with emphasis on the EU (52%), national government (47%), and regional and local bodies (35%). Accountability is also externalized from individual efforts (28%) to business and industry (41%), similar to EU citizens. That is consistent with **perceptions** of 74% of individuals arguing insufficient government action (EU, 2023a). PT public general environmental attitudes junct display loud concern and willingness to act in environmental protection and nature conservation (EU, 2024).

1.4.3. Portuguese understanding of climate change

Attitudes have cognitive foundations (Ecker et al., 2022); which explains why education and **quality information** induce momentum for elevating climate inertia states into what scholars call positive [social] tipping points, optimal conditions for rearranging social values and norms (Geiger & Swim, 2016; Kutney, 2024; La et al., 2024; Mendy et al., 2024; Powell et al., 2023; Ranney & Clark, 2016; Schmid & Betsch, 2019). Thereafter, the state of play of Portuguese public understanding of climate change is revised below.

Overall, PT respondents scored above EU average (6.9 out of 10.0) during the European Investment Bank 2021-2022 Climate Survey (European Investment Bank, 2022; Froimovici & Hoyer, 2024). Survey measurements consisted of **closed-ended questions** to evaluate understanding of climate science by quantifying knowledge about climate change **causes** separated from knowledge about **consequences**, which used a probabilistic cluster sampling that ensured generalizability (Cohen, 2007). 71% defined climate change correctly, but still many lagged in answering adequately (Froimovici & Hoyer, 2024). About 79% knew human activities (e.g., deforestation, agriculture, industry, and transportation) were causing climate change (Froimovici & Hoyer, 2024). On the other hand, a reasonable ratio of 12% thought climate oscillations were caused by natural phenomena and 9% made confusion around ozone depletion and global warming (Froimovici & Hoyer, 2024). On climate science, particularly consequences, 93% of the PT public knew that ACC is a public health problem (Froimovici & Hoyer, 2024). Most could manage ACC consequences, referring appropriately about food insecurity (91%), sea level rise (85%), and migration (79%) (Froimovici & Hoyer, 2024).

Participants were less knowledgeable about **climate action essentials** with an average score of 4.4 out of 10 points. Besides only 31% of total municipal waste weight is recycled in PT (EUROSTAT, 2025) and transportation emissions are the largest of any sector in

national GHGs inventory (Ritchie & Roser, 2020), PT citizens insist arguing about recycling (82%) and overflowing their daily mobility routines to public transportation (77%). A clear example of the action gap. Furthermore, just a few (21%) could reason that control over speed limit would reduce driving emissions (Froimovici & Hoyer, 2024), despite driving a car being a common symbol to illustrate a direct source of emissions (which are imperceptible by our macroscopical senses). 63% are unaware that reducing clothes purchases reflects a positive climate impact (Froimovici & Hoyer, 2024). In spite of, recent news about Artificial Intelligence (AI) colossal environmental impact in Portuguese media (Pequenino, 2024), PT citizens did not comprehend indirect emissions from using digital devices (Froimovici & Hoyer, 2024). The majority was unaware of buildings' insulation relation to lower heating and cooling energetic demand (Froimovici & Hoyer, 2024), which can be a conceptual lacuna or rather a byproduct of Portugal's energy poverty profile (discussed in Horta et al., 2019).

Most of the public does not deal with climate concepts as frequently as researchers do. And it would be naïve to expect people with unrelated jobs to know everything about it from memory. These indicators, however, stress another more disturbing facet of lay people's **skills**. Whenever an individual identifies transportation as a leading contributor to emissions but fails to associate motor combustion with GHGs release, their conceptual understanding is considered *enough* in contrast with their cognitive and reasoning ability. Another conclusion is that closed-ended questions can overestimate public understanding. Organisation for Economic Co-operation and Development (OECD) latest report highlights that literacy, numeracy, and problem-solving in PT are below average (OECD, 2024). Systems thinking is a paramount skill associated with positive values of nature and climate action. Skillful systems thinkers perceive greater scientific consensus and climate risk while valuing nature more (Lezak & Thibodeau, 2016). Content analysis below provide latent cues about systems thinking of a Portuguese general audience.

Aside from individual cognition, understanding is also influenced by content itself and **information sources**. PT citizens prefer to consume scientific content from social media, with Facebook on top of the list followed by YouTube and Instagram (Delicado et al., 2020). A recent independent research project corroborated those results (Mede et al., preprint). Meanwhile, scholars insist on high awareness and low climate science skepticism (following Froimovici & Hoyer, 2024), but see limited access to quality information constraining climate action (Delicado et al., 2020). Social media is a prolific environment for misinformation dissemination due to its unrestricted content filtering (Martens et al., 2018). Despite PT believing in education's capacity for bringing forward eco-friendly behaviors (EU, 2024),

individuals see formal science communication as the least frequent information source (Mede et al., preprint) while climate education captivates low funding (Carvalho et al., 2013).

PT citizens have favourable climate change attitudes, inclusively superior to EU average (EU, 2023a). At the same time, they resort more often to the “I don’t know” option than EU average in all sets of questions and variables (EU, 2023a). Climate change transcends climate science boundaries to economics, psychology, sociology, and other fields (Santos, 2021; Stern, 2007); lack of knowledge about key adjacent concepts explains confusion around statements related to climate change economics where most failed to answer, e.g., “The costs of the damages due to climate change are much higher than the costs of the investments needed for a green transition”, where EU=11% and PT=16% did not know, or “Reducing fossil fuel imports from outside the EU can increase energy security and benefit the EU economically” where EU=10% and PT=14% did not know likewise. National researchers are worried about lack of public sense in climate science and climate action (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000). So, does the knowledge gap persists along the Iberian Atlantic shore?

Scaling up **climate literacy** is a step forward in climate mitigation and resilience (IPCC, 2023). PT mitigation and resilience plans (EU, 2021) are downscaled by low investment in citizen education. Science communication and climate education showed evidence of improving attitudes and promoting eco-friendly behaviors (Kutney, 2024; La et al., 2024; Mendy et al., 2024; Ranney & Clark, 2016; Schmid & Betsch, 2019), even superficial talks are better than climate silence (Geiger & Swim, 2016). Risk communication can be a lever to pull action (Irwin, 2019). The majority of PT citizens consider themselves exposed to climate change consequences (EU, 2023a), thus offering an opportunity for communicating the risks to general audiences to reassess their values and behaviors.

1.4.4. Overview of Portuguese behaviors, attitudes and understanding

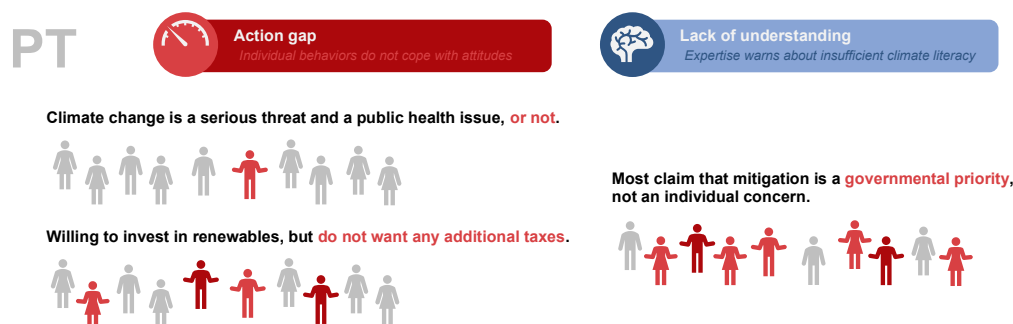


Figure 4. Schematic summary of Overview of Portuguese behaviors, attitudes and understanding sub-section.

1.5. Misinformation and climate change denial

Hearing backstage conversations showed that actors were part of a group of cabals. Not all of them knew every line of the climate science script, but they were aware of human responsibility. Backstage conversations gave privileged intel about their real intentions and enabled upgrading the cipher, a device built for decoding their hidden messages. Now, the script can be translated.

Everyone enjoys a good plot twist, and action deniers are audacious performers in twisting the climate plot. The curtain is finally opening. Shhh... Silence. The play is starting. Let just remind the reader that you are going to assist the most jocular one from all science denial stories, the first act narrates about (1) misinformation, the second act spotlights (2) denial machine and rhetorical strategies, the third act plugs to (3) artificial intelligence and social media, and, just before changing scene, ends dramatically with fourth and final act (4) action denial.

1.5.1. Misinformation

False information has a bipartite classification; spreading misinformation ascribes disseminating false content without intent to harm, in contrast, disinformation carries falsehoods deliberately to harm (UNDP, 2025). Most of the time, deniers' primary objective is unknown to researchers who use *misinformation* to refer to all types of false information (Cook, 2020). Whenceforth, without knowing actual intentions, misinformation refers likewise to disseminating unreliable content.

Misinformation is a threat to Humanity (World Economic Forum, 2023), followed by extreme weather events and societal polarization. IPCC models a growing frequency and severity of extreme weather events (IPCC, 2023). Misinformation shakes social networks, contributing to polarized environments (Cook et al., 2016; Cook & Lewandowsky, 2016; Hart & Nisbet, 2012; McCright & Dunlap, 2000). European Digital Media Observatory (EDMO) reported a significant growth in misinformation across Europe last year (EDMO, 2024a), with climate and environmental-related misinformation corresponding to meaningful loads in most EDMO fact-checking briefs (EDMO, 2025b).

Misinformation is deniers' primary resource (Cook, 2020), similar to antivaccine supporters (Schmid & Betsch, 2019), flat Earth endorsers (McIntyre, 2019) or any contrarian group with unscientific beliefs (Ecker et al., 2022). Misinformation compromises public acceptance of climate change and deters support for policy and action (Lewandowsky, 2021).

Specific sociodemographic profiles are more susceptible to fake news, including less educated, younger and conservatives (Kyrychenko et al., 2025). Similar profiles appear

more frequently among climate science deniers (Biddlestone et al., 2022; Dunlap et al., 2016; Ejaz et al., 2024; Hart & Nisbet, 2012; Kulin et al., 2021; Lewandowsky & Oberauer, 2016; McCright & Dunlap, 2000; McCright et al., 2016; Schmid & Betsch, 2019).

Interventions can act precautionarily before misinformation enters (**pre-bunking**) or after being exposed to it (**de-bunking**). More often, interventions target epistemic beliefs, advocate science, attitudes, countering motivated rejection of science, and/or capacitate fact- and logic-checking (Mendy et al., 2024), ultimately trying to enhance misinformation detection and/or reduce its side effects.

Inoculation is a successful pre-bunking approach (reader can explore *Cranky Uncle* available for download on the App Store and Google Play or see Cranky Uncle, 2025); inoculation can deliver accurate information (**fact-based interventions**) or showcase rhetorical techniques used by deniers (**logic-based interventions**) (Cook et al., 2017; van der Linden et al., 2017). Both approaches got positive evidence for downscaling misinformation influence (Cook et al., 2017; Ecker et al., 2022; Maertens et al., 2025; Mendy et al., 2024; Schmid & Betsch, 2019; van der Linden et al., 2017). **Inoculation** is not alone; science communication and education can amplify positive beliefs and fact-checking skills (Kutney, 2024; Ranney & Clark, 2016), serving as pre-bunking approaches even without a pre-established goal to intervene in misinformation.

Cognitive scientists applied **message framing** and education activities in debunking interventions. Message framing consists of displaying information with appealing perspectives to specific audiences (McCright et al., 2016), e.g., framing climate change as a national security issue. National security concerns most American citizens, especially conservatives. Americans, with emphasis on right-leaning endorsers, are less prone to support climate action and are more active in climate negation (e.g., Hart & Nisbet, 2012; McCright et al., 2016). Then, message framing rearranges information while preserving scientific accuracy. Other understudied debunking approaches are conflict and deliberation, e.g., attributing a stakeholder role to resolve conflicting scenarios, and exposing agendas, i.e., practitioners occupy intervention by unidirectionally or collaboratively identifying misinformation flaws to reach a final verdict (Mendy et al., 2024).

If climate science is robust and interventions show promising results, why does misinformation persist in public perceptions? **Misinformation is comparable to a disease** (that is why authors named a preventive approach as inoculation). Even after interventions and accepting corrective content, cognitive perimeters are hijacked by a **continued influence effect** that calls falsehoods back to rule in decision-making (Ecker et al., 2022; Maertens et al., 2025). That explains why boosting interventions afterwards drew promising

results (Maertens et al., 2025). Most debunking research suffers from collecting data immediately after misinformation exposure (Ecker et al., 2022), where continued influence effect goes untraceable.

Not rescuing specific information happens more regularly than people admit. During those awkward moments, humans decide through heuristics or escape along motivated reasoning forced by confirmation bias, i.e., to maintain their status position. **Heuristics** are cognitive shortcuts that facilitate action when intel is unavailable or forgotten in decision-making processing (Ecker et al., 2022). **Motivated reasoning** happens when one strives to lead a discussion to conclusions of their exclusive interest (McCright et al., 2016). **Confirmation bias** is a psychological process where people aspire, or intrinsically hope, to confirm their previous beliefs (UNDP, 2025). These cognitive processes happen undeliberately most of the time. Meta-cognition, a reasoning process over one's own cognition, can be a valuable tool to counter their negative effects.

1.5.2. Rhetorical strategies

Scientists reached a consensus about human responsibility (Oreskes, 2004). However, dismantling market-oriented economic settings where capital generation rules economies makes it more costly to bear than altering public perceptions. And thereby the climate change denial machine, or denial machine, set their operating scheme in motion using rhetorical strategies from tobacco industry disinformation campaigns (Oreskes & Conway, 2010).

Denial campaigns are more psychologically complex than most expect (Cook et al., 2016). Cognitive scientists systematized **climate denial strategies** (Cook, 2017; 2020) and claims (Coan et al., 2021). They grouped them into taxonomies, like those of biology, to accelerate denial recognition and mitigation. Taxonomies demonstrate that science denial is structured and easily contaminates public opinion, as most can be heard in everyday life.

Cook adapted antecedent works in denial rhetoric to climate science denial (Cook, 2017), specifically the **FLICC taxonomy**. FLICC acronym comes from five superintended rhetorical strategies, i.e., False experts, Logical fallacies, Impossible expectations, Conspiracy theories, and Cherry picking (separated from other informal logical fallacies). Cook (2020) offers an elegant overview of the philosophical backgrounds behind climate science negation strategies, under FLICC taxonomy, with practical examples.

While FLICC summarized strategies (how deniers deny), Coan and colleagues redeem a computer-assisted taxonomy for **climate denial claims** (what deniers use to say), known as Computer Assisted Recognition of Denial and Skepticism (CARDS). The **CARDS**

taxonomy classifies hierarchical super-claims, sub-claims, and sub-sub-claims (Coan et al., 2021), like a matryoshka or any taxonomy network of biology. Every other claim fits into one of five super-claims, (1) global warming is not happening (science denial), (2) human greenhouse gases are not causing global warming (science denial), (3) climate impacts are not bad (science denial and action denial), (4) climate solutions won't work (action denial), and (5) climate movement/science is unreliable (science denial and action denial).

1.5.3. Denial machine

Markets and industries are more concerned about **losing profit** than shifting to climate-friendly consumption (Kutney, 2024). Additionally, oil companies' revenues rely on fossil fuel consumption. Industries, fossil fuel companies and corporations united assets and resources to bolster the business-as-usual agenda by discrediting climate science, founding what researchers call **denial machine**.

Denial machine is a system operating with the main goal of creating and spreading misinformation. Its cunning works can be exposed by FLICC and CARDS taxonomies (Coan et al., 2021; Cook, 2017; 2020; Rojas et al., 2024; Zanartu et al., 2024). Multiple stakeholders operate the denial machine under **vested interests**, from corporate representatives, industry lobbies, politicians, journalists and think tanks (Cook, 2020; Farrell, 2016; Lewandowsky, 2017; 2020; Oreskes & Conway, 2010; Supran et al., 2023).

Historically, misinformation can be traced back to Germany 20th century, Nazism birthplace. The Nazi narrative transfigured public opinion about Jewish people, segregating and slaughtering them violently. Nazi propaganda got so deeply rooted that, despite triggering World War II, antisemitism worldviews still affect Jewish population (e.g., shaping Palestine-Israel conflict). That shows misinformation continued influence effect. During a recent pandemic, **conspiracy theories** involving vaccines and 5G towers led to civil disobedience in the United Kingdom with infrastructural damage to telecommunication supplies (Parveen & Waterson, 2020). Additionally, conservative misinformation outlets uphold responsibility for the violent riot made by Capitol invaders after Biden won USA election (Ecker et al., 2024).

Fossil fuel companies omitted evidence of anthropogenic interference in the greenhouse effect since the 1980s (Oreskes & Conway, 2010), including projections of mean surface temperature increase with CO₂ concentrations building up in the atmosphere (Supran et al., 2023). Denial machine influence over politics was clear when George H. W. Bush withdrew the USA from Kyoto Protocol, making climate change beliefs a politicized topic ever since (Farrell, 2016; McCright & Dunlap, 2000).

One clear example of **cherry-picking** was identified when using data from short time frames (Easterling & Wehner, 2009) to make **anecdotal allegations** sound like if Earth was cooling when climate requires longer time series data. At the same time, think tanks published reports full of criticism (Farrell, 2016). Until the denial machine campaigns contaminated journalism and all media (Cook, 2017).

Many educational resources carry climate-related information without explicitly recognizing human accountability (Kutney, 2024). Members of the American Republican Party showed publicly their contrarian opinion about it (Milman, 2024). Conservative campaigns, opinions, and governmental acts about climate change under Trump's administration are clear examples of climate change counter movements. Making irreparable damage by restricting American leading expertise from attending IPCC meetings for preparing the Assessment Report 7, upcoming in 2027, cutting funding in environmental-related projects and claiming that climate change is a giant hoax (Canon et al., 2025; Stockton, 2025). Scientists have drawn supportive results of an association between climate misinformation and perceptual gaps featuring lay audiences about scientific consensus and their peers support for action (Andre et al., 2024; Oreskes & Conway, 2010; Supran et al., 2023).

In summary, denial and misinformation instigate societal conflict, public health issues, and democratic instability while downscaling reactive measures to contemporary challenges, like climate change. To countermeasuring denial machine campaigns, science communication and education are valuable assets for capacitating people from all ages and backgrounds to identify rhetorical strategies and inaccurate perceptions (Geiger & Swim, 2016; Kutney, 2024; Lewandowsky, 2021).

1.5.4. Artificial intelligence and social media

Until recently, humans were accountable for conceiving and carrying out information, including falsehoods (Harari's insightful book *Nexus* delivers a lucid discussion about this subject). Since 20th century finale until now, Western societies faced unprecedented loads of information (Hills, 2019; Santos, 2021). Societies failed to adapt to democratized access to digital information and content creation while industry and corporations took advantage of it, for instance, the climate change denial machine (Oreskes & Conway, 2010). Misinformation overflow in societies, in a *Post-truth* (Lewandowsky et al., 2017), contaminating public conversation around science and eroding public trust in science while influencing decision-making processes (Cologna et al., 2024; 2025; Ecker et al., 2024).

With **social media** allowing democratic clearance for publishing content unchecked, online platforms became optimal channels for spreading misinformation (d'I. Treen, 2020; Hills, 2019; Rathje et al., 2022; Richards & Worden, 2024; Rojas et al., 2024). Importantly,

generative artificial intelligence (GenAI) advancements enabled non-human entities to trace human profiles and deliver information of their interest, including misinformation, and also to create deceiving content at a vertiginous pace (Galaz et al., 2025; Richards & Worden, 2024; van der Ven et al., 2024). GenAI can persuade, coerce, assault and surveil at an individual and global scale by impersonating humans, creating synthetic identities, and manipulating digital content (Richards & Worden, 2024).

On one hand, AI can drive climate action through monitoring GHGs emissions, reducing climate modelling uncertainty, improving energy efficiency, waste and water management, preventing wildfires, optimizing food and supply systems and giving early warning of extreme weather events and hazards (UNFCCC, 2024). On the other hand, contemporary GenAI affects perceptions about climate change (Galaz et al., 2025) and decision-making (Richards & Worden, 2024).

Examples of altered opinions through climate negation conceived by GenAI were manifested during Slovakia's 2023 elections (Zuidijk, 2023) and offshore wind power plants discouragement (Berger, 2023). Additionally, new GenAI features can impersonate celebrities (Gecsoyler, 2024; Richards & Worden, 2024). For instance, Sir David Attenborough, a prestigious BBC wildlife documentary producer and one of the oldest living naturalists known for directing and starring in *Life on Earth* (1979), watched by over 500 million people, *Life in Colour* (2021), and recently premiering *Ocean* (2025) book and documentary. All content needs double-checking in the *post-truth* era (Ecker et al., 2024; Lewandowsky et al., 2017). Sir David Attenborough devoted a lifetime to promoting environmental awareness and nature conservation, earning credibility from supranational assemblies, national governments, scientists and general audiences (Richards, 2013). Anyone with access to GenAI can overwrite years of credibility built by respectful personalities, including Sir David Attenborough, disguising themselves like him for a video to pass on false ideas about climate science and action.

Climate misinformation abounds on social media (Ecker et al., 2024; Rojas et al., 2024). Social media platforms seek strategies to make users stay there for longer periods, their collectives depend on that. Social media integrates artificial intelligence (AI) to expand users' scrolling periods and improve advertising targets. AI catalogues preferences to put users into niches, known as **echo chambers** (UNDP, 2025), reinforcing their pre-conceived beliefs with **algorithmic bias** (Martens et al., 2018; UNDP, 2025). Whenever beliefs get more dogmatic (at least, in one's psych), correction becomes more difficult intrinsically due to cognitive dissonance, backfire effect, and seeking less information (McCright et al., 2016; Hart & Nisbet, 2012; Ecker et al., 2022; Schmid & Betsch, 2019; Schulz et al., 2020). Social

media and rapid content creation (with GenAI) feed this feedback system. Portuguese public preference for consuming scientific information more regularly in social media (Delicado et al., 2020; Mede et al., preprint) plus their low understanding of climate change (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000) and below-average cognitive performance (OECD, 2024) make alarming warnings. We recommend a research agenda to combat persistent breadth evidence of GenAI and AI models or social media effects in the Portuguese public opinion about science (see [Insight 2](#)).

1.5.5. Action denial

Most misinformation-related studies shed light on science denial (Fasce et al., 2023; McCright et al., 2016; Schmid & Betsch, 2019), conspiracy theories (Biddlestone et al., 2022), and fake news detection (Kyrychenko et al., 2025). Though, action denial studies saw climate delay discourse in media (Supran & Oreskes, 2021), texts produced by think tanks (Cook, 2017) and fossil fuel deceiving campaigns (Supran et al., 2023), rarely scholars dived deeply into understanding action denial psychological presence in general audiences underscoring a **critical research gap** in misinformation psychology.

Recently, a survey suggested that only 3% of the Portuguese population were climate change deniers, a concept referring to science denial and action denial simultaneously. Conclusions were drawn from a single close-ended multiple-choice question by quantifying those who selected “climate change is a hoax” (Froimovici & Hoyer, 2024). Albeit sampling obeyed a probabilistic cluster sampling, which supports external validity (Cohen et al., 2007), above all, their instrument oversimplified climate change denial. At best, measurement would capture science denial despite other experiments required more complex instruments to examine science denial in general audiences (Biddlestone et al., 2022; Ejaz et al., 2024; Fasce et al., 2023; Hart & Nisbet, 2012; Kulin et al., 2021; Kyrychenko et al., 2025; Lewandowsky & Oberauer, 2016; McCright et al., 2016; Schmid & Betsch, 2019). That same data from the European Investment Bank (Froimovici & Hoyer, 2024) observed that 12% attributed natural phenomena as causes of ACC and 9% felt into slippery terrain between ozone depletion and global warming, demonstrating instrument inconsistency even for quantifying science contrarians. Whereby, action denial empirics face another constraint derived from oversimplifying denial psychology.

Action denial consists of narratives with hidden objectives to postpone the adoption of less emission-intensive behaviors by casting doubt deliberately, undeliberately, or coercively on the **need to act**, and/or **human agency to resolve**, and/or **urgency to deliver mitigation plans**, motivated by ideology, vested interests, psychological shortcuts and/or seeking to

avoid individual and social failure, including cognitive dissonance and group derogation avoidance.

Action denial operates under two strategies, discourses of delay and misleading framing, that superintend multiple approaches hiding different agendas (Damico et al., 2023).

Discourse of delay strategy breaks into (1) redirecting responsibility, (2) pushing non-transformative solutions, (3) surrendering to the problem, and (4) emphasizing the downside. **Misleading framing** strategy makes use of (1) individualizing responsibility, (2) technological optimism, (3) fossil fuel solutionism, (4) climate risk uncertainty, and (5) greenwashing. All approaches are described below (see [Instrument and variables](#) subsection).

Denial machine saw climate science consolidating (Cook et al., 2016). So it has been swapping climate science denial with action denial claims by trading assaults on science reliability with action denial (Damico et al., 2023; Lamb et al., 2020; Supran et al., 2023; Supran & Oreskes, 2021). The most frequent claim is that *climate solutions will not work* (Rojas et al., 2024), a clear example of surrendering to the problem approach (Damico et al., 2023). Here, an exploratory assessment focuses on surrendering to the problem, emphasizing the downsides, technological optimism, climate risk uncertainty and greenwashing psychological presence.

1.5.6. Misinformation and climate change denial at a glance

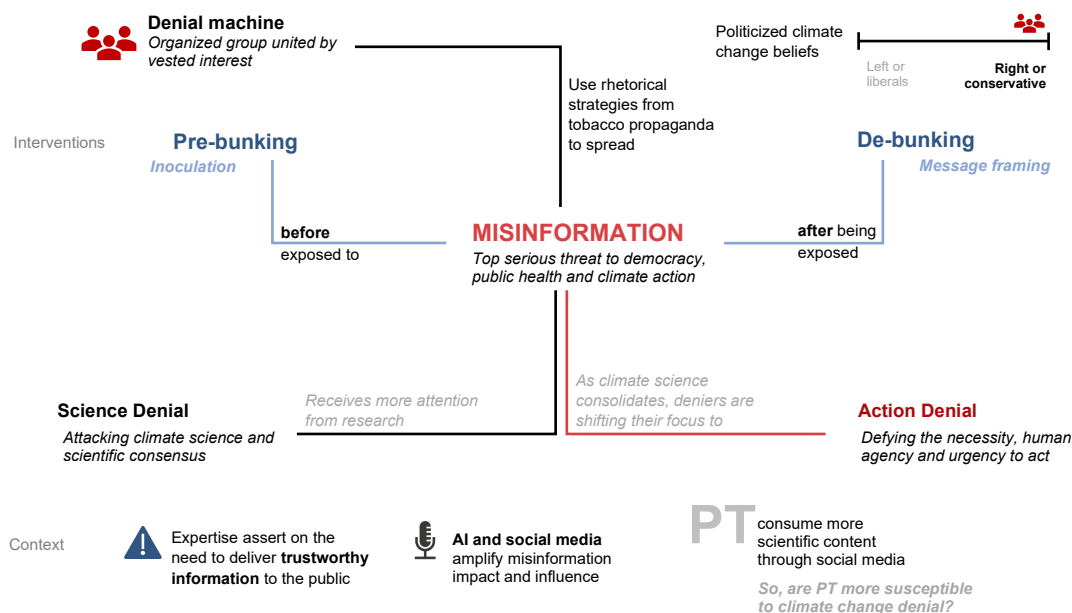


Figure 5. Schematic summary of the Misinformation and climate change denial sub-section.

2. Methods

Watching deniers play made possible to upgrade the cipher, a cryptographic device to decode hidden messages behind the contrarians discourse. The time for describing how the cipher was crafted and how it was tested finally came.

2.1. Research questions

RQ₁ What are psychometric foundations of action denial attitudinal disposition?

Only a few studies focus on action denial, mostly text or media analysis (Damico et al., 2023; Fasce et al., 2023; Lamb et al., 2020; Supran & Oreskes, 2021) and denial machine propaganda (Rojas et al., 2024). There is a lack of a measurement for assessing action denial psychological presence in general audiences. Action denial is a multifaceted construct (e.g., Damico et al., 2023); constraining any classification through a one-item scale, like Froimovici & Hoyer (2024) did for science denial. Action denial spreads through (1) discourses of delay and (2) misleading framing operationalized by multiple approaches. To quantify action denial, a 5-point Likert scale converted approaches into dispositional formulations.

RQ₂ What are attitudes towards climate change among a Portuguese general audience?

Despite a substantial corpus indicating that individuals are more psychologically moved to climate action, behavioral change itself is insufficient (IPCC, 2023). Most studies focus on specific attitudes (Cook et al., 2017; Fasce et al., 2023; McCright et al., 2016), i.e., climate science awareness, climate change awareness, scientific consensus beliefs, and support for climate action appear. Portuguese underestimated scientific consensus and agreement around climate change severity (Većkalov et al., 2024). Reports verify that public concern and awareness of climate change increased (Flynn et al., 2024). Others, while corroborating those results, suggest a low rate of deniers (European Investment Bank, 2022; Froimovici & Hoyer, 2024). Quantifying adjacent attitudes to action denial contributes to comprehending its psychological underpinnings, which can offer valuable information for an exploratory research agenda.

RQ₃ Which sociodemographic variables prevail among action deniers?

Science denial prevails among specific sociodemographics (e.g., Cook, 2020; McCright et al., 2016). Right-leaning individuals are more active in science denial (Biddlestone et al., 2022; Dunlap et al., 2016; Ejaz et al., 2024; Farrell, 2016; Hart & Nisbet, 2012; Kulin et al., 2021; Lewandowsky & Oberauer, 2016; McCright & Dunlap, 2000; McCright et al., 2016; Schmid & Betsch, 2019), and religious people too (Fasce et al., 2021; McCright et al., 2016). Those same variables show reduced science awareness, climate change awareness and

support for climate action (Cook, 2020; Lewandowsky & Oberauer, 2016; Lewandowsky et al., 2020). Other demographics, sex, education, and household income predicted climate change attitudes, though sample-dependent (Cook, 2020; Lewandowsky & Oberauer, 2016; Kutney, 2024). Women, literate, and high-income people are usually associated with greater climate change awareness and support for climate action (Cook, 2020; McCright et al., 2016) and are less susceptible to misinformation (Ejaz et al., 2024; Kyrychenko et al., 2025). Nevertheless, science denial messages appear in conversations of people from all educational backgrounds (Cook, 2020; Ecker et al., 2024; Kutney, 2024). Light sheds upon that overlooked and urgent gap whereas action denial sociodemographic profiles are still unknown.

RQ₄ How many climate change action deniers are quantified in a Portuguese population of laypeople?

Few works have trialed action denial in lay populations, mostly theoretical and analyzing corporative and media messages (Damico et al., 2023; Fasce et al., 2023; Lamb et al., 2020; Supran & Oreskes, 2021). And so, quantifying action deniers within general audiences remains overstated. Although a quantification could deliver important information for future research and practice.

RQ₅ What is the understanding of climate action and climate science among a Portuguese general audience?

Literate individuals exhibit more climate awareness (Kutney, 2024; Ranney & Clark, 2016), congruent with the cognitive dimension of attitudes (Campbell, 1963; Eagly, 1992; Ecker et al., 2022). Higher education students are expected to be among the most knowledgeable citizens. Surveys suggest high understanding levels in Portugal (Fraembs & Drobnič, 2024; Froimovici & Hoyer, 2024), while experts are concerned about the opposite (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000). Those dissonant results need to be reevaluated by testing essential knowledge of climate action and climate science.

RQ₆ What misrepresentations of climate science are found in a Portuguese population of laypeople?

RQ₆ emerged after evaluating understanding. Many individuals carried misrepresentations of climate science. Those misleading beliefs are misinformation. They do not hold to scientific ground (Ranney & Clark, 2016). Misinformation effects can last after corrective measures due to continued influence effect and other cognitive side effects (Ecker et al., 2022; 2024). Thus, studying misperceptions about climate science contributes to assessing understanding and creates opportunities for interventional research and reactive measures to offset continued influence effects.

RQ7 How does understanding of climate action and climate science relate to action denial and other climate attitudes in a Portuguese general audience?

Attitude formation has a cognitive foundation apart from social and affective factors (Campbell, 1963; Eagly, 1992; Ecker et al., 2022). Albeit the public has been described as knowledgeable about climate change (Fraembs & Drobnič, 2024; Froimovici & Hoyer, 2024), most studies still collected data using closed-ended questions that potentially bias understanding. Others assert a lack of climate education (Kutney, 2024). Low understanding can translate into a higher propensity to accept and incorporate science denial (e.g., Cook, 2020). Congruently, knowledge dissemination activities (or fact-based interventions) produced favorable attitudinal change (Maertens et al., 2025; Ranney & Clark, 2016; for interventions' effect in science denial see Mendy et al., 2024 and Schmid & Betsch, 2019). Hence, addressing this gap can highlight paths for future research and practice.

2.2. Research design and sampling

2.2.1. Research design

Design aligns with **survey research** followed by a mixed-methods approach during a second stage, in agreement with classifications made by literature on educational research methodology (Coutinho, 2014; Cohen et al., 2007; Mills & Gay, 2019). Design consisted of one observation without variable manipulation or a control group. This research design served **descriptive objectives** congruent with a first-exploration of action denial psychological foundations. There persists an underdevelopment of action denial psychology. To address it, a psychometric scale assessed action denial psychological presence in a general audience population.

Psychology has been shaped by positivist research since statistical inference made generalizations possible. Although quantitative data can ascribe important overarching assumptions to large populations and ensure generalizability through probabilistic sampling (Coutinho, 2014; Cohen et al., 2007; Mills & Gay, 2019), it translates reality through a narrow lens. Socioconstructivism defies positivist restrictions of observing psych and social phenomena through quantitative data (Bauer & Falade, 2021; Piaget, 1964; Vygotsky, 1978). Misinformation investigation benefits from crossing **qualitative data** with **quantitative data** to produce more granular conclusions (Ecker et al., 2022). Not many studies are found to do so, and analyzing qualitative data on large populations is an arduous task. Therein, a **mixed-methods approach** tried to bridge that gap by curating dual-nature data, quantitative and qualitative, and cross-analyzing it for a large sample ($n = 562$).

2.2.2. Sampling

Sampling was outside a probabilistic sampling procedure. Higher education students do not represent the public in its broadest sense, however, selection avoided surveying individuals with formal education in climate or environmental sciences to ensure a layperson population. And results confirm it. Literature on research methodology classifies this type of sampling as **convenience sampling** (Coutinho, 2014; Mills & Gay, 2019) because it gathers data without control over randomness or sociodemographics. It serves as an exploratory guide for further research without guaranteeing generalizations.

2.3. Instrument and variables

Instrument consists of a survey with two open-ended questions, one scale to trial action denial and three other scales previously validated by McCright et al. (2016), Cook et al. (2017) and Fasce et al. (2023). Instrument is available in [Appendix 1](#).

2.3.1. Quantitative variables

A multitude of attitudes can influence climate action and policy support. Variable selection addressed their ability (1) to compare data with recent reports (Fraembs & Drobnič, 2024; Froimovici & Hoyer, 2024), and (2) to evaluate dispositional underpinnings of action denial. Other climate-related variables settled psychological latent ground for ensuring action denial internal validity by presenting important hints of **action denial** psychology.

Reports from Fraembs and Drobnič (2024) and Froimovici and Hoyer (2024) raised concern about overestimating attitudes and oversimplifying science denial. Thereafter, we focused on well-known attitudes and adapt McCright et al. (2016), Cook et al. (2017), and Fasce et al. (2023) reliable measurements for **climate change awareness** (Cronbach's alpha: $\alpha = 0.89$), **climate science awareness** ($\alpha = 0.91$), and **support for climate action** ($\alpha = 0.91$) converting all items into a **5-point Likert scale** (from Strongly disagree = 1 to Strongly agree = 5). While McCright and colleagues observed an American population, Fasce and other researchers studied a Mediterranean population.

To set up instrument, items were selected based on empirical relevance and contextualization with Portugal. Items were adapted according to Portuguese context (e.g., swapping *Climate change will be a problem for United States* with *Climate change will be a problem for Portugal*) or enhanced their dispositional engagement and scientific accuracy (e.g., instead of *Climate change will be a problem for Portugal* trade to *Climate change is and will be a problem for Portugal*). A total of 21 items of McCright and colleagues' instrument and Fasce and colleagues' instrument (based on McCright's) caught our

attention, where seven of them focused on climate science awareness, eleven measured climate change awareness and three cared about support for climate action.

Unlike other attitudes, the action denial curtain had not slid aside. So, item formulation required access to works inside and outside psychology. Action denial uses climate delay discourses and misleading framing strategies (Damico et al., 2023). These strategies have hidden objectives behind application, similar to science denial taxonomies (FLICC and CARDS). Climate delay discourse strategy features redirecting responsibility, pushing non-transformative solutions, surrendering to the problem and emphasizing the downsides. Misleading framing suppresses action by individualizing responsibility, technological optimism, fossil fuels solutionism, climate uncertainty allegations, and greenwashing. Most rhetorical techniques are diluted during argumentation, as science denial research systematizes (e.g., Cook, 2020). Whence, filtering them to deliver a dispositional formulation without overlapping techniques was a hard task that action denial scale strives to meet. Systematizing action denial approaches eased setting up action denial scale (see Figure 6 for a snapshot of all action denial approaches with a description of their hidden agenda).



Figure 6. Description of action denial strategies, discourse of delay (on the left) and misleading framing (on the right). Those descriptions were woven following Damico et al. (2023), Fasce et al. (2023), Lamb et al. (2020), Supran and Oreskes (2021), and UNEP (2025) works.

Six items spotlighted climate risk uncertainty (3), technological optimism (2) and greenwashing (1). Another three items focused on emphasizing the downside (2) and surrendering to the problem (1). Not all items survived factorial analysis, but they are all mentioned below, along with an explanatory walkthrough (Figure 7). Complementing scale with missing techniques is a potential research avenue.

 Instrument		Casted items after factorial analysis
Item 1	It's prudent to wait for the results of more research before we reduce our nation's greenhouse gas emissions. Climate risk uncertainty	AD-1
Item 2	We have too many problems to deal with to try to reduce our nation's greenhouse gas emissions. Climate risk uncertainty	
Item 3	Overall, trying to reduce our nation's greenhouse gas emissions will be bad for our nation. Surrendering to the problem	AD-2
Item 4	If we make abrupt consumption shifts socioeconomic problems will emerge and we will never tackle climate change. Emphasizing the downsides	
Item 5	Individual and public investment in climate change mitigation will weaken human prosperity. Emphasizing the downsides	AD-3
Item 6	Climate change is not a problem yet, it is merely a possible risk. Climate risk uncertainty	AD-4
Item 7	Most of the products, goods, and services which we consume and acquire are already very sustainable, their own campaigns show it clearly. Greenwashing	AD-5
Item 8	Sooner or later scientific and technological evolution will solve climate change. Technological optimism	
Item 9	If we continue to increase the world economy, we won't need to worry about climate change. Technological optimism	AD-6

Figure 7. Script roll upfront shows Action Denial factor (AD) items with iconographical and verbal reference to strategies and approaches, respectively. Another script roll, behind, sneak peeks items that have survived factorial scrutiny.

2.3.2. Qualitative variables

To pass on for those **knowledge-related variables**, defining “public”, “general audiences”, and “lay people” aligns instrument’s intent and at the same time prepares for the upcoming subsection. The definition of “public” depends on geography, deriving from its heterogeneous constitution of individuals, as the vocable itself assumes particular humans have unmatched features. That gives meaning to “individuals”. Whenever science communication research defines a population as “public” it presumes that individuals are lay people about a particular subject and represent the entire population (Bauer & Falade, 2021; Burns et al., 2003; Mejlgaard & Stares, 2009). Whenever scholars mention “general audiences”, similar to “lay people”, they expect a population composed of individuals with limited understanding of a particular subject without ensuring they fully represent the entire population.

The final sample ($n = 562$) is conceptualized as a “general audience” obtained through a convenience sampling procedure. Nevertheless, this set of participants is expected to be close or above the Portuguese average in knowledge and cognitive abilities because they attended higher education. Based on definitions of “general audiences”, “lay people” and sampling procedure, understanding assessment focused exclusively on climate science core tenets, specifically **climate action essentials** and **climate science essentials** that interact with psychological constructs and behaviors (Weber & Stern, 2011).

Most surveys only extracted information on participants’ knowledge through closed-ended questions (Bauer & Falade, 2021). While experts are concerned about lack of public understanding (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000), survey research reports differ (Fraembs & Drobnič, 2024; Froimovici & Hoyer, 2024). Therefore, understanding was tested through **open-ended questions** on climate action and climate science essentials.

Q₁ What are the behavioral changes in your daily activities that may contribute further to mitigating climate change? Indicate at least three.

The first question inquires into their environmental-related practices in daily routines. Individuals are not supposed to reach perfect behavioral standards, it is a virtual scenario far from Western citizens’ reach. However, informed people are supposed to know how they can be more sustainable. Q₁ makes them ask what habits they are willing to change according to their preferences and capacity to resist when turning behaviors into habits. Then, from selected possible changes, they reflect on which would yield a more significant emission reduction. Additionally, Q₁ facilitates delivering a correct answer to the next one, explained below.

Q₂ Are you able to mention at least three causes and three consequences of climate change? If so, indicate them.

The second question delves into causes and consequences. Those fundamental concepts intrinsically resonate with human accountability and climate impact tenets (Weber & Stern, 2011). Others reckon it as mechanistic learning (Ranney & Clark, 2016). We prefer to refer to it as knowledge or understanding of climate science essentials. While acknowledging that knowledge and understanding are meridional concepts with hierarchical positions; knowledge is often associated with recalling a piece of information when a context is advanced (our comprehension of mechanistic learning), understanding, however, consolidates climate science essentials with the ability to map and navigate throughout relations while forecasting systemic causalities by materializing them in cognition (see Weber & Stern, 2011 for a lucid discussion on public understanding of climate change).

Systems thinking is a pivotal cognitive skill with promising results to shift to pro-environmental values and beliefs (Lezak & Thibodeau, 2016). With that in mind, content analysis of Q₂ inferred more than their knowledge by revealing valuable insights into their systems thinking and relational reasoning capacity. ACC is a complex domain (Incropera, 2015; Rittel & Webber, 1973). Nevertheless, dealing with core concepts and practicing **systems thinking** attributes can improve understanding (Lezak & Thibodeau, 2016).

Answering proficiently to Q1, e.g., “to become more sustainable, I can eat plant-based and walk more frequently while joining a 100% renewable energy pack supplying my household”, would simultaneously give three cues on causes of ACC, specifically food production, transportation, and energy production.

2.3.3. Ethics

Research ethics is an elementary requirement whenever investigating beings, including humans. Ethical recommendations for best practice research were safeguarded during this investigation (Coutinho, 2014; Cohen et al., 2007; Mills & Gay, 2019). Instrument was approved by the Ethical Committee of the Faculty of Sciences of the University of Porto (CE2024/p169) before application. In all observational moments, participants were informed orally and by text that (1) their participation was **voluntary**, and (2) at any moment they could **cease it without any penalty**, while reiterating that (3) data gathered from their response was treated confidentially only by research team members to ensure **anonymity**.

2.3.4. Sociodemographic information

Climate change is a moral and ideologically charged domain (Dunlap et al., 2016; Farrell, 2016; Kulin et al., 2021; McCright & Dunlap, 2000; Weber & Stern, 2011). Systematic

evidence has shown that specific sociodemographic profiles are more frequent among science deniers (Cook, 2020). Instrument probe information of other sociodemographic variables, like sex, age, nationality, education, civil status, children, labour, income, political orientation, and religiosity.

2.4. Participants

Initial sociodemographic recognition collected information about **age** (average years = 21), **nationality** (international students = 140), **civil status** (single = 575), **children** (with at least one child = 20), and **labour** (student-worker = 49). Applying substantial treatment ensured control over outliers and excluded invalid entries. The final sample of $n = 562$ was composed mainly of **females** (63.7%) and **religious people** (81.9%). Individuals from all economic backgrounds, however, **low-income households** (84%) prevailed compared to middle- and high-income households together (16.0%). The majority of them concluded high school (76.3%) and, by the time of data collection, all of them were **at least attending a degree program**. Some already had a degree (16.0%) while just a few had concluded a master's degree (0.9%). Along the political spectrum, they lie less on left-wing or liberals and left (2.5% and 21.2%, respectively) than on **right and far-right or conservatives** (27.4% and 4.8%, respectively). The remaining 44.1% choose center ideology. In summary, participants came from low-income households while being literate, religious and right endorsers in politics.

2.5. Procedure

2.5.1. Software

Data treatment and graphical design occurred in Microsoft Excel version 2503 (Build 18623.20208 Click-to-Run), and Statistical Package for Social Sciences (SPSS) version 29.0.0.0 (241) and then updated to 30.0.0.0 (171) computed **statistical calculations**.

2.5.2. Data treatment

Psychometric valuation translated a 5-point Likert scale into an ordinal variable where Strongly disagree = 1, Moderately disagree = 2, I do not know = 3, Moderately agree = 4, and Strongly agree = 5. Construct means were calculated, granting characteristics of continuous variables to scales. Dichotomous sociodemographics were treated like dummy variables; sex data were converted to Male = 0 and Female = 1, and religiosity to non-religious = 0 and religious = 1. Politics data were coded with Left-wing or liberals = 1, Left-centered = 2, Center = 3, Right-centered = 4, and Far-right or conservative = 5, with ordinal variable characteristics. Income and education were treated similarly, although did not produce relevant results. Knowledge-related variables were converted into ordinal variables

by treating Fail = 1, Insufficient = 2, Sufficient = 3 and Good = 4 to avoid neutralizing the effects of failing when Fail = 0.

2.5.3. Exploring action denial psychological construct procedure

In quantitative research, psychologists, including environmental psychologists, have been occupied, beyond other tasks, with improving instruments by (1) making them reliable and accurate, (2) optimizing them until the fewest items capture the construct adequately, and (3) ensuring that results can be generalized.

Here, the proposal of an action denial factor makes a preliminary investigation of its psychological presence through a 5-point Likert scale. Undertaking action denial and other attitudes through recommended statistical inference tests used whenever enhancing any scale performance delivered a reliable and concise instrument, following Marôco (2021).

Procedures are taken to address research questions (RQ_n) and research objectives (O_n); the following were taken after questioning about action denial psychometric foundations (RQ₁) while aiming to set a proper scale to quantify it (O₁).

Before entering into a full description, concepts urge clarification. Validity can be divided into external validity, or results generalizability, and **internal validity**, which oversees measurement reliability and accuracy (Coutinho, 2014; Mills & Gay, 2019). Convenience sampling condemns any generalization a priori (Marôco, 2021). Then, internal validity was a primary target. While accuracy can only be inferred from parallel or continued observations to compare instrument performance along different observations or populations, **reliability** showcases intra- and inter-factorial consistency with single observations (Coutinho, 2014). Internal validity is part of (1) making them [ref., instruments] reliable.

Participation suffers when instruments are too long. Fortunately, factorial analysis is part of (2) optimizing them [ref., instruments] until the fewest items are capable of capturing construct adequately. Factorial analysis is a series of back-and-forth statistical tests and optional paths of inputting and removing items until reaching optimal versions with fewer items still capturing the construct (Marôco, 2021).

Different factorial analysis methods exist (see Marôco, 2021 for systematized intel on factorial analysis methods); in line with research intent and preconditions of sampling and variables achieving univariate distribution, but not multivariate distribution, the **exploratory factorial analysis of the principal component** fitted correctly. We define factorial analysis of the principal component as a process that weights factor loadings through multiple components (or constructs); a set of items aggregate into a factor by presumed presenting

heavier loadings in a particular component (or construct), then, factor analysis redeems factorial loadings along all components, thus, it can pinpoint dissident behavior, like loading overlap throughout components, that affect overall **capture of the principal components**.

Now, concepts are sufficiently displayed. Description of the procedure can start. Firstly, preconditions for factorial analysis ensured idoneity of statistical parametric tests, with respect to **normality** and **sampling adequacy**.

Afterwards, a preliminary calculation of Cronbach's alphas suggested factorial reliability without factorial analysis refinement. After conceiving that Action Denial would load negative weights along other components besides its own. We followed guidelines from Marôco (2021) on principal component analysis to select the *varimax* rotation method during extraction. For instance, climate change awareness is expected to be non-analogous to action denial. Those expectations of an orthogonal factorial model were confirmed by prompting better results with the *varimax* method.

Undertaking factors through factorial analysis of the principal component identified an unexpected component, a product of factor loadings overlapping between undesirable components. Later, it was recognized as the Scientific Consensus Beliefs factor.

Support for Climate Action did not survive factorial analysis due to poor performance. Meanwhile, a second factorial scrutiny showed items 2, 4 and 8 of Action Denial factor had overlapping behavior in the rotative component array. Likewise, item 19 of Scientific Consensus Beliefs factor was diluted throughout undesirable components. Therefore, items 2, 4, 8 and 19 were dismissed from the final version of the scale.

Thereafter, a series of reliability tests weighed four versions of Climate Change Awareness, starting with 7 items. Weighting Cronbach's alphas discrepancies of those four versions resulted in a more concise factor with 5 items without significant reliability loss (for classification parameters of Cronbach's alpha values see Taber, 2018).

Before advancing the final version of the scale with four factors and 22 items, reliability tests reassessed internal consistency of all factors through Cronbach's alphas. None of the factors saw a representative decrease in their overall consistency. The 4-factor 22-item scale achieved a 59.3% of capture through rotative square loadings sums by the fourth component. A stepwise graphical description was designed to condense more information on the procedure for exploring action denial psychological construct (Figure 8). There indicative results were displayed to avoid jeopardizing description of what was done and why.

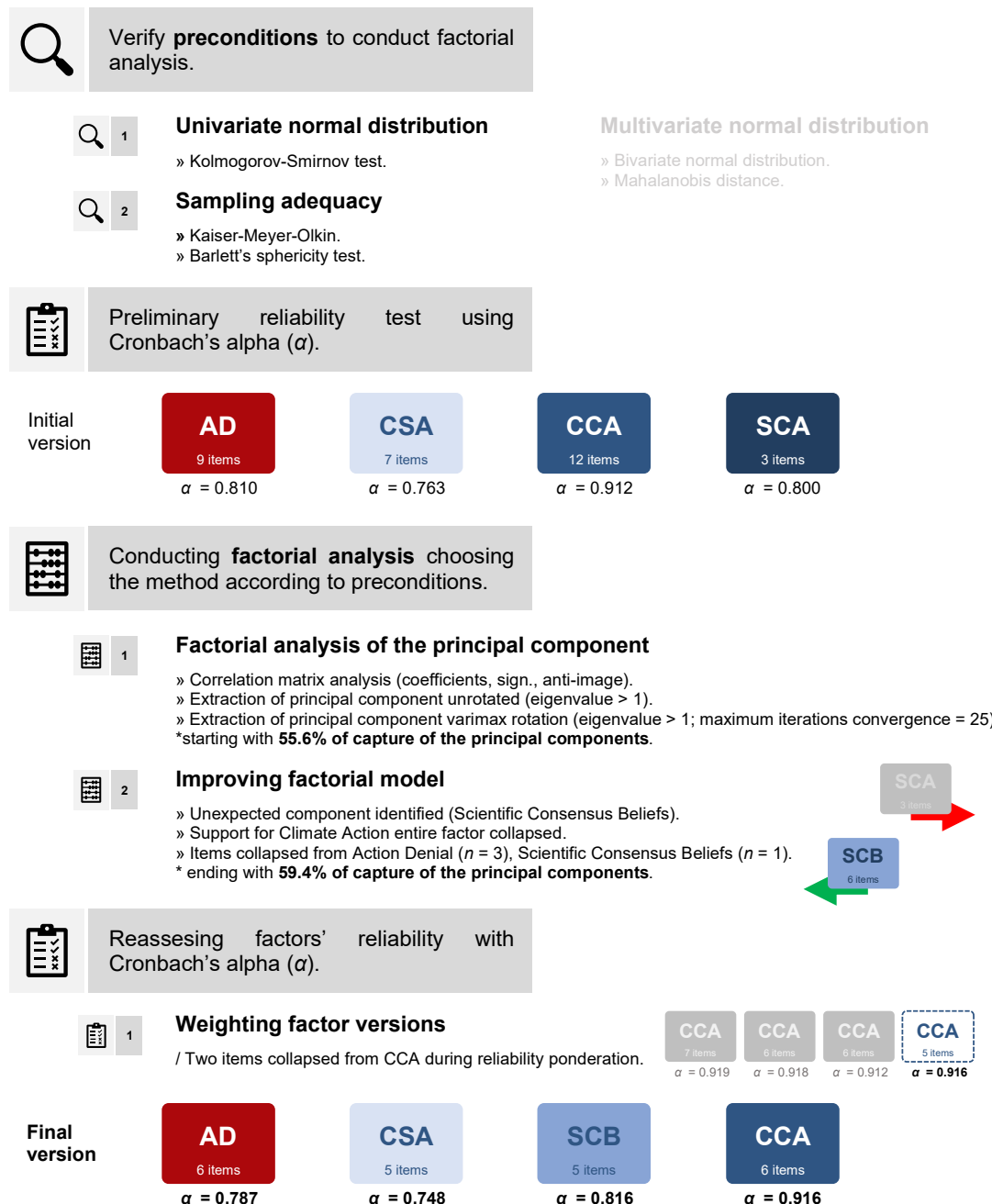


Figure 8. Stepwise information on exploring action denial psychological construct procedure. Abbreviations refer to Action Denial factor (AD), Climate Science Awareness (CSA), Scientific Consensus Beliefs (SCB), Climate Change Awareness (CCA), and Support for Climate Action (SCA).

2.5.4. Attitudes toward climate change and action denial procedure

After instrument validation, studying attitudes (RQ₂) and sociodemographic interference upon them (RQ₃) involved quantifying climate change attitudes (O₂), exploring attitudes influence over action denial psychological presence (O₃) and which sociodemographics prevail among action deniers (O₄).

Kolmogorov-Smirnov (K-S) test examined normal distribution for individual items and factors under Monte Carlo's parameters with a 95% CI. That ensured statistical parametric inference suitability, as literature suggests (e.g., Marôco, 2021).

Mean ($\bar{x}$) and standard deviation (SD) values were computed for all attitudes, including Action Denial. **Descriptives** for variables opened up the discussion around attitudes among a Portuguese population of higher education students. **Correlation tests** (Pearson's exhibited, and Spearman's and Kendall's Tau-b excluded) scrutinized attitudes interplay both in intensity (weight) and direction (signal) with a two-way parameter and CI=95%. P-values' significance can reject the null hypothesis (H_0), hence variables relate significantly (for categorizing parameters of correlation intensity see Mills & Gay, 2019).

Thereafter, **linear regressions** undertook Action Denial as the dependent variable, or predictor, while inserting other attitudes separately using the *enter* method in the independent variables field. Model adequacy was controlled through plotting standardized residuals along the number of observations and by applying Chi-square tests. Politics and religion performed adequately in linear regression tests. In a similar way, a stepwise graphical description was designed for attitudes toward climate change and action denial procedure (Figure 9).

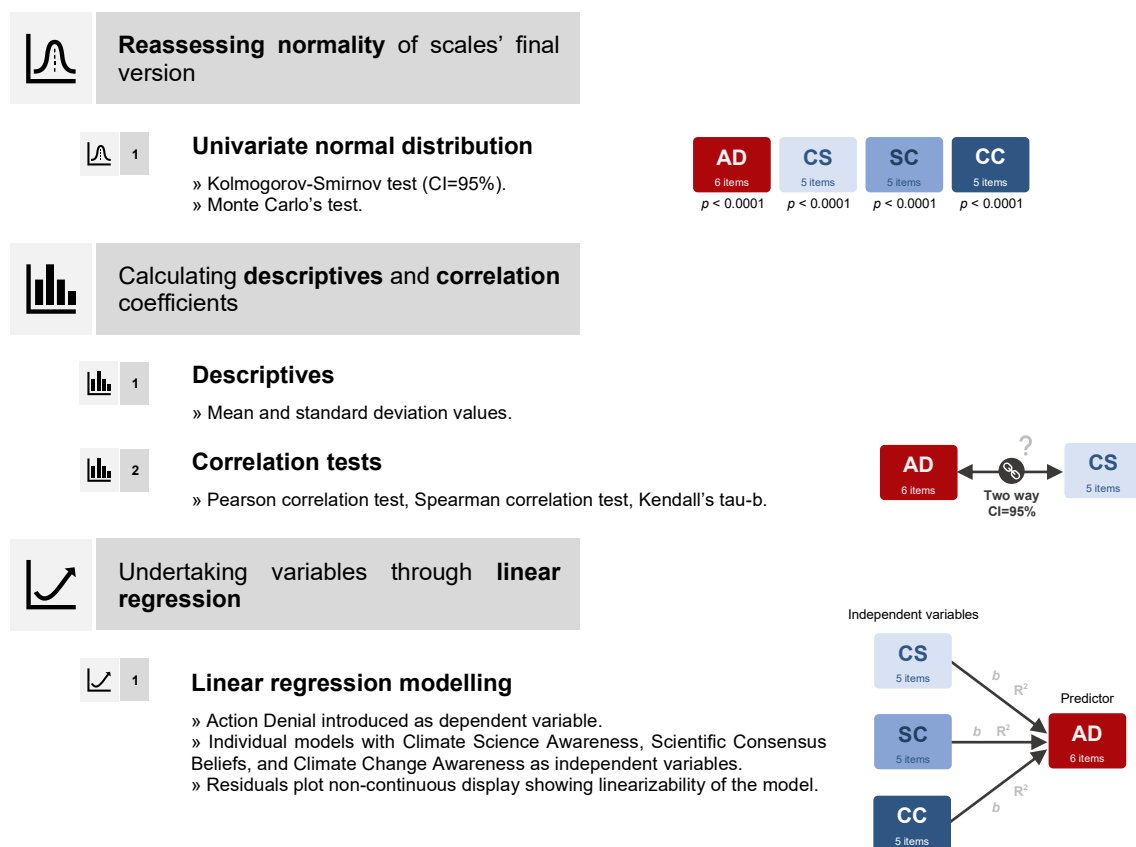


Figure 9. Stepwise information on the procedure of attitudes towards climate change and action denial. Abbreviations refer to Action Denial factor (AD), Climate Science Awareness (CSA), Scientific Consensus Beliefs (SCB), and Climate Change

Awareness (CCA). Along with those abbreviations, Confidence Interval (CI), coefficient of determination (R^2), and Beta (b) exhibit suppressed forms too.

2.5.5. Quantifying action deniers procedure

Previous procedures were supported by empirical evidence and theoretical works. Facing lack of a clear method for quantifying action deniers (RQ₄) while aiming to quantify them in our population's attitudes (O₅), indulged efforts to address that research gap by proposing a methodology for quantifying action deniers. Methodology starts by establishing **reference values**. Participants whose means exceeded those reference values are considered action deniers. We estimated two baselines relative to our data; one resulted from adding Action Denial mean and SD, while the other summed Action Denial median (Med) to SD.

Those two methods (mean and median) prompt a significant percentage of action deniers, yet yield different values. Thereby, **sensitivity** estimated elasticity across methods and denial profiles considering unilastic properties whenever scores got close to 1 and inelastic when they fall apart from 1. Sensitivity calculated the quotient between methods' difference in profile means (see [Quantifying action deniers](#) for sensitivity results). Thereafter, average values for attitudes were compared across profiles (deniers and non-deniers) and methods (mean and median). A stepwise graphical description was designed to systematize the procedure of quantifying action deniers (Figure 10).

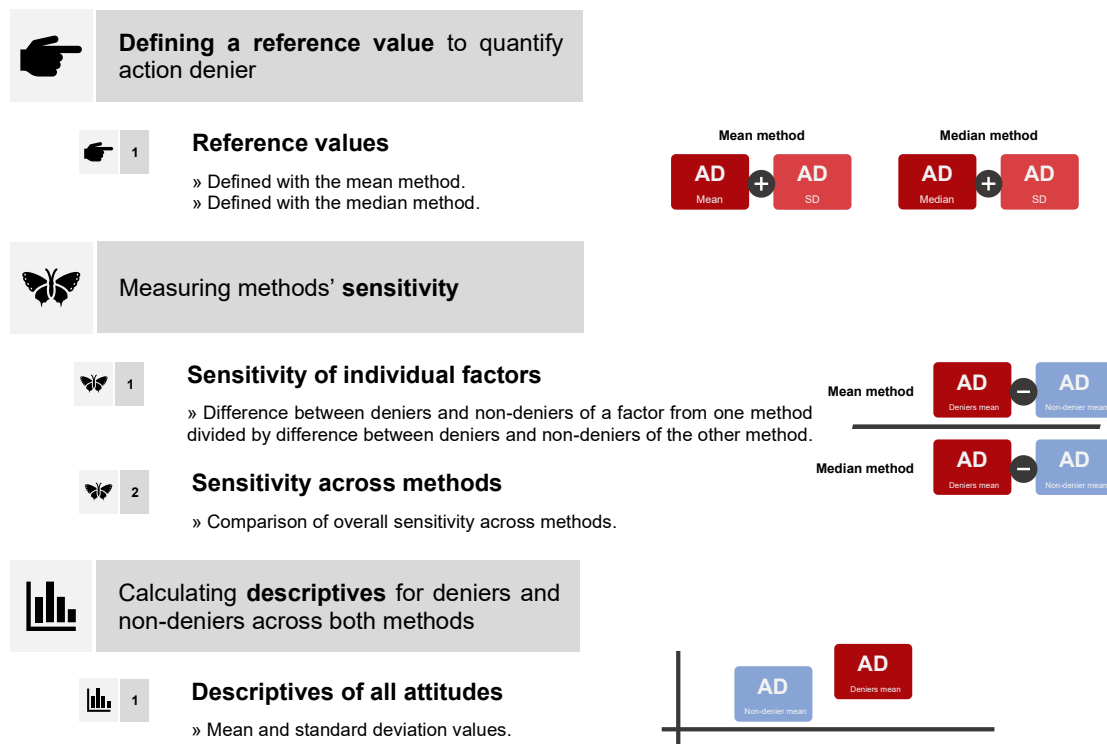


Figure 10. Stepwise information on the procedure of quantifying action deniers. Abbreviation refers to Action Denial (AD).

2.5.6. Understanding climate change and action denial procedure

Literacy reports and expert disagreement evoked questions around general audience understanding (RQ₅), which we sought to find proper ways of evaluating (O₆). After running through data, misrepresentations of climate science alarmed us (RQ₆) and understanding effects on attitudes too (RQ₇), wherein cognitive-dispositional links get tricky (O₇).

Two **open-ended questions** shed light on climate action essentials and climate science essentials of causes and consequences. Qualitative data passed through **content analysis** during knowledge evaluation and quantification of descriptors, an analytic method that searches for qualitative communalities in responses and groups them into common descriptors (Coutinho, 2014).

Whereas qualitative data tested knowledge, answers that did not find their way among descriptors were considered invalid or, at best, inaccurate. Knowledge valuation ranged from Fail = 0 valid entries to Good = 3 valid entries, which differs from data treatment. Entries were cumulatively summed up to a maximum of 3 entries (ref., Good).

Another methodological caution refers to list descriptors for analysis. A myriad of actions can be climate actions, from avoiding paper use to walking instead of driving a car, or even limiting prompts in Artificial Intelligence chatbots. Almost any action serves to reduce indirect emissions. In logical terms, a single table could not systematize all possible actions. Content analysis of climate action essentials acknowledges entries with scientific coherence, verbal assertiveness, and meaningful potential for reducing emissions. Often, respondents stacked up more than one entry in the same descriptor, e.g., “avoiding using car, biking, and walking”. Delivering answers with this kind of similarity oversimplifies the task of answering itself. Valuation counted all entries, grading it Good = 3, albeit cumulative valuation can overestimate understanding of climate action. In addition, consulting IPCC reports (IPCC, 1990; 2007; 2021) facilitated setting up a list of pre-defined descriptors for appraising climate science essentials (access [Appendix 2](#) for consulting the list).

Every entry that could fit into one of those descriptors and messaging it with scientific accuracy counted as one valid entry. Some *actions* were invalid due to unspecific or arbitrary explanations of their influence over climate; e.g., “pollution” appeared without a concrete intervention (i.e., *reduce* pollution), or the type of pollution it referred to. Another example, “diminish chemical products” associated with chemophobia rather than tackling ACC. Entries with insignificant or ambiguous meaning were likewise invalid, e.g., “shut the tap while brushing my teeth” and “limiting GHGs release”, respectively. ACC affects and will affect the hydrological cycle (IPCC, 2023), and freshwater is a valuable resource. Although shutting the tap is a way of reducing water use, it does not offset emissions significantly.

The first stage featured **knowledge-related valuation**, with parallel data treatment. That built up to count those failing (0 valid entries), or delivering insufficient (1 valid entry), satisfactory (2 valid entries) and good (3 valid entries) answers to climate change knowledge essentials while treating data with Fail = 1 up until Good = 4.

In the second stage, **quantifying the frequency of descriptors** highlighted that few joined most of the total of valid entries in climate action essentials and climate science essentials. The gateway response effect explains those tendencies and propensity for persistent superficial understanding of climate change essentials among lay people.

During third stage, several misrepresentations of climate science could be grouped into seventeen categories. Some of those **misrepresentations of science or inaccuracies** depict inadequate information, for instance, confusion around microplastics and GHGs. While others suggest fragile systems thinking, e.g., saying that pollution is a consequence (when, at best, pollution is a cause). Many persist in carrying falsehoods that have last for long in public opinion and popular scientific culture, a clear example is arguing that the ozone hole boosts global warming (Weber & Stern, 2011). Misconceptions were cumulatively quantified. Then, submitting misconceptions frequency and Action Denial data to correlation tests (Pearson's, Spearman's rho, and Kendall's tau-b) provided information about the interplay between knowledge and action denial psychology.

The fourth stage started by calculating Correlation coefficients (parametric and non-parametric: two-way, CI=95%). It showcased the direction and intensity of knowledge-related variables and Action Denial. Obtaining significant p-values enables rejecting the H_0 , thus assuming that variables interplay significantly. Then, linear regression models undertook knowledge-related variables as independent variables to predict Action Denial, the dependent one, with the *enter* method and 95% CI while plotting residuals. Those procedures statistically corroborated that **understanding influences engaging in action denial**. Additionally, calculating knowledge-related mean values across denialistic profiles (deniers and non-deniers) for both methods stood consistent with previous results.

The fifth stage assessed **knowledge effects on attitudes**. Correlation tests were applied before linear regression models took knowledge-related variables as independent variables and attitudes as dependent variables with equal parameters. A stepwise graphical description was designed for procedure of understanding climate change and action denial (Figure 11).

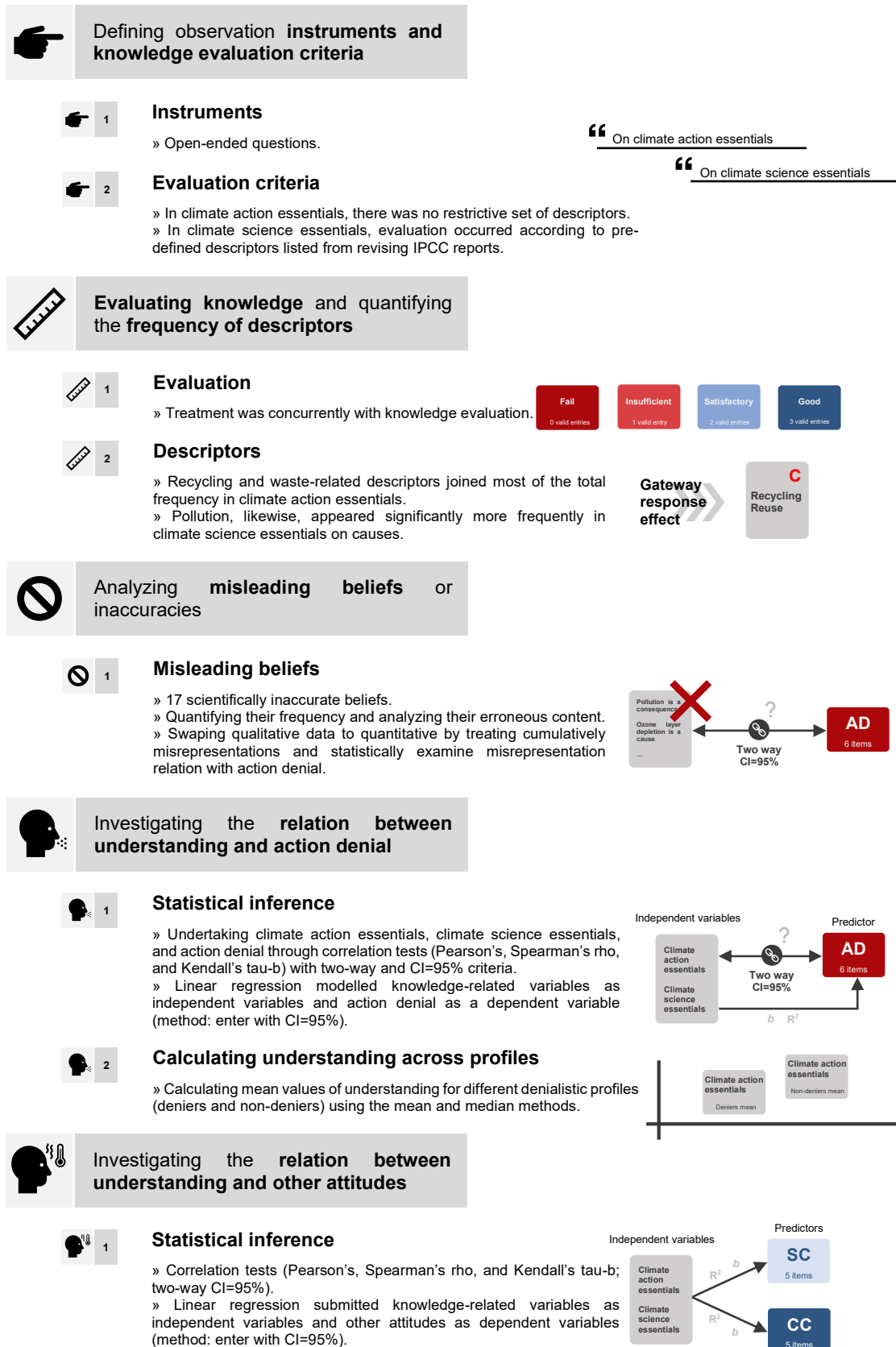


Figure 11. Stepwise information on the understanding climate change and action denial procedure. Abbreviations refer to Action Denial factor (AD), Scientific Consensus Beliefs (SCB), and Climate Change Awareness (CCA). Along with those abbreviations, Confidence Interval (CI), coefficient of determination (R^2), and Beta (b) exhibit suppressed forms too.

3. Results

Sneaking up into action denial backstage revealed their hidden high awareness of climate science. That is why action deniers no longer engage in neglecting climate science but, instead, deceive the need, urgency and capacity to act. While sneaking up into the backstage, either audience's murmurs were too loud and obstructed hearing or their conversation was codified too. Finally, circular narratives proved to carry encrypted messages. We strove to decode every piece of their script, but time was getting to an end. Thankfully, we decoded a sufficient part just before the play started.

Play began and so the cipher started decoding hidden messages. As play ended, cryptographic improvements gave cipher the ability to capture more than half of their code. Surprisingly, at the same time, the cipher emitted signals coming from audience whispers. The cipher should be tested on the public as soon as possible. Thesis started the moment the curtain shut.

After days of data collection with the cipher on general public conversations, instrument reliability for [exploring the action denial psychological construct](#) was assessed (targeting [O₁](#) and [RQ₁](#)). Their script contained interesting relations between [attitudes toward climate change and action denial](#) ([O_{2,3,4}](#) and [RQ_{2,3}](#)). Performative acting could not hide from the method for [quantifying action deniers](#) ([O₅](#) and [RQ₄](#)). After all these distant observations, approximation with a mixed-methods approach gathered more granular intel about level of [understanding and action denial](#) (addressing [O_{6,7}](#), and [RQ_{5,6,7,8}](#)).

3.1. Exploring the action denial psychological construct (RQ₁)

Action denial has even less evidence gathered in Portugal, especially of general audience polls. Supported by previous valid scales (Cook et al., 2017; Fasce et al., 2023; McCright et al., 2016) and works on action denial (Damico et al., 2023; Lamb et al., 2020; Supran & Oreskes, 2021), instrument includes a 5-point Likert scale (for more information, access [Instrument and variables](#) and [Appendix 1](#)).

3.1.1. Normality

The first step was to examine normal distribution to proceed with statistical parametric inference tests (Marôco, 2021; Nimon, 2012). In addition to Q-Q plots, Kolmogorov-Smirnov (K-S) test observed normality parameters for factor means and casewise items showing significant p-values ($p < 0.0001$ CI=95%), including with Monte Carlo examination ($p < 0.0001$ CI=95%). Null hypothesis (H_0) was rejected as variables obeyed univariate normal distribution parameters. Whenceforth, statistical inference is considered reliable (Marôco, 2021).

3.1.2. Prerequisites for conducting factorial analysis

To better capture a construct, scales can undergo through factorical analysis (Marôco, 2021; Mills & Gay, 2019), but variables must comply with stringent methodological criteria including but not exclusive to normal distribution criteria, sampling adequacy, and internal consistency (Marôco, 2021; Nimon, 2012, Taber, 2018). Kaiser-Meyer-Olkin (KMO) value of 0.928 and Bartlett's sphericity test ($\chi^2 = 7807.806$ $p < 0.0001$) indicate sample and factorial model adequacy, according to Marôco (2021). Cronbach's alphas (α) showcased a preliminary assessment of internal consistency. All factors performed well, with Action Denial (AD) reaching $\alpha = 0.810$. Climate Science Awareness (CSA) and Support for Climate Action (SCA) got inferior results (CSA: $\alpha = 0.763$; SCA: $\alpha = 0.800$), while Climate Change Awareness (CCA) outperformed all above (CCA: $\alpha = 0.912$).

3.1.3. Exploratory factorial analysis

Factorial analysis has successive advances and retreats (Marôco, 2021). To maintain clarity and avoid overburdening the reader, intermediate steps are dismissed here in delivering the final version of the instrument.

Logically, action denial psychological valuation is antagonistic to other factors. It would lead to cognitive dissonance to esteem climate action and simultaneously be an active action denier. Expectations got confirmed when an orthogonal factorial model yielded better results than parallel factorial models during principal component analysis with *varimax* rotation (following recommendations made by Marôco, 2021).

Component matrix and rotative component matrix yielded five components. Questions about overlapping factorial weights arose when four factors with few items each were distributed through five components. Overlapping factorial weights refers to high factor loadings (values in principal component matrices) across different components (Marôco, 2021). It shows interfactorial *noise* that contaminates internal capture of principal components. The rotative component matrix possessed overlapping items from CSA, CCA, and SCA factors. Notably, items from CSA and CCA appeared fragmented across components #1, #2 and #3. Analysing the verbal content revealed references to scientific consensus messages. Denying scientific consensus is among the most common yet effective forms of denial (e.g., Cook, 2020). Finding that items 14, 15, 17, 18, 19 and 20 formed a distinct component (component #3) created an opportunity to explore another psychological construct known for gaslighting public perceptions around ACC. Whereafter, component #3 identified items that later defined a factor called Scientific Consensus Beliefs (SCB). Full arrays from principal components outputs (see Table 1) guided instrument improvement to increase capture of the principal components.

Item		Straight					Rotative				
		Component					Component				
Initial factor	Item	1	2	3	4	5	1	2	3	4	5
AD	1	-0.090	0.624	0.268	0.083	-0.128	-0.003	0.683	-0.086	0.071	-0.113
	2	-0.046	0.492	0.278	0.299	0.103	-0.010	0.616	0.098	-0.175	0.031
	3	-0.253	0.433	0.309	0.058	0.029	-0.122	0.540	-0.192	-0.089	0.022
	4	0.116	0.540	-0.035	0.105	-0.077	0.005	0.478	0.200	0.212	-0.098
	5	-0.042	0.643	0.210	0.165	0.017	-0.039	0.693	0.059	0.032	-0.013
	6	-0.297	0.661	0.119	-0.021	0.101	-0.308	0.652	-0.103	0.121	0.069
	7	-0.009	0.633	0.182	0.018	0.148	-0.054	0.642	0.036	0.124	0.156
	8	0.005	0.597	-0.076	-0.009	-0.393	-0.026	0.491	0.027	0.370	-0.371
	9	-0.252	0.673	0.223	-0.058	0.039	-0.203	0.693	-0.174	0.128	0.053
Component load		-0.867	5.296	1.477	0.640	-0.161	-0.759	5.488	-0.134	0.795	-0.264
CSA	10	0.492	0.336	-0.384	-0.359	-0.059	0.172	0.033	0.283	0.720	0.074
	11	0.380	0.412	-0.372	-0.457	0.084	0.042	0.094	0.210	0.752	0.221
	12	0.251	0.610	0.095	0.031	0.010	0.149	0.569	0.183	0.250	0.051
	13	0.305	0.526	-0.132	-0.168	-0.213	0.155	0.354	0.150	0.526	-0.116
	14	0.537	0.091	-0.284	0.253	0.090	0.236	-0.016	0.613	0.128	0.024
	15	0.509	0.212	-0.386	0.133	0.221	0.113	0.028	0.637	0.274	0.160
	16	0.463	0.414	-0.272	-0.245	-0.192	0.224	0.171	0.250	0.640	-0.070
Component load		2.937	2.601	-1.734	-0.812	-0.060	1.090	1.233	2.327	3.290	0.343
CCA	17	0.557	0.122	-0.264	0.297	0.152	0.240	0.028	0.659	0.094	0.071
	18	0.610	0.093	-0.292	0.311	0.120	0.281	-0.010	0.697	0.107	0.041
	19	0.639	0.109	-0.283	0.080	0.069	0.328	-0.044	0.559	0.289	0.081
	20	0.622	0.147	-0.289	0.295	0.024	0.309	0.033	0.674	0.163	-0.037
	21	0.785	-0.058	0.225	-0.135	0.021	0.752	-0.042	0.183	0.182	0.233
	22	0.702	-0.085	0.128	0.053	-0.216	0.696	-0.064	0.242	0.113	-0.077
	23	0.654	-0.125	0.128	0.182	-0.251	0.668	-0.070	0.279	0.001	-0.161
	24	0.782	-0.167	0.276	0.054	-0.060	0.808	-0.080	0.228	-0.001	0.104
	25	0.742	-0.093	0.334	-0.063	-0.086	0.805	-0.013	0.111	0.077	0.126
	26	0.754	-0.179	0.128	0.092	-0.196	0.745	-0.142	0.282	0.059	-0.064
	27	0.738	-0.099	0.239	-0.137	-0.057	0.749	-0.071	0.125	0.164	0.159
	28	0.827	-0.162	0.246	-0.046	-0.115	0.845	-0.112	0.194	0.109	0.091
Component load		8.413	-0.496	0.574	0.983	-0.595	7.228	-0.588	4.233	1.356	0.567
SCA	29	0.472	0.086	0.192	-0.191	0.551	0.324	0.090	0.170	0.093	0.676
	30	0.613	0.004	0.283	-0.166	0.357	0.548	0.046	0.142	0.081	0.531
	31	0.745	-0.086	0.235	-0.081	0.054	0.720	-0.049	0.194	0.110	0.240
Component load		1.830	0.004	0.711	-0.438	0.962	1.592	0.088	0.505	0.284	1.447

Table 1. Straight and rotative component arrays. These coefficients correspond to the principal component straight (on the left) and rotative (on the right) component matrices conducted under the *varimax* rotative extraction method in SPSS version 29.0.0.0 (241). Cell colors make allusive representations of constructs representativeness in factor loadings from pre-defined

factors and *ad hoc* factor provided by factorial scrutiny. Abbreviations refer to Action Denial factor (AD), Climate Science Awareness (CSA), Climate Change Awareness (CCA) and Support for Climate Action (SCA) factors.

Another factor with overlapping loadings demanded special attention. Support for Climate Action (SCA) did not achieve previously reported psychometric performance (McCright et al., 2016). Although SCA had satisfactory internal consistency ($\alpha = 0.702$), ambivalent factor loadings across component #1 and component #5 were responsible for adding an extra component without contributing to internal capture of the principal components. By the fourth component, capture of the principal components was equal to 51.5% compared to a deloaded fifth component that added only 4.1%. Before redeeming SCA, correlation tests show undesirable co-occurrence in direction and significance.

These results support the decisions of treating SCB individually and removing SCA henceforth. Restructuring scales resulted in a 4-factor 28-item version composed of AD with nine items, CSA with five, SCA with six and CCA with the remaining eight. We repeated factorial scrutiny, having observed items 2, 4, and 8 slightly overlap in component #3 conceived under scientific consensus messages. There are expectations that action deniers can acknowledge scientific consensus; their main intent is not to disprove science but to postpone action (e.g., Damico et al., 2023). Additionally, item 19 (from SCB) bolstered factorial entropy. Individually assessing inter-item correlations with Fisher z-transformations (with CI=95%) for superior and inferior limits of occurrence spotlighted psychometric skewness among items 2, 4, 8, 29, 30 and 31. Similarly, items 19, 22 and 23 decrease overall significance.

Addressing length and extensiveness of instruments is critical for ensuring participation and reducing early dropouts or response bias (Nimon, 2012). CCA contained a larger number of items that granted it a strong consistency ($\alpha = 0.912$). We made four hypothetical versions for renewing CCA. They were evaluated using four iterations in reliability tests; first without any removal, second removed item 23, third collapsed item 22 and fourth retained items 22 and 23. In spite of the first iteration yielding higher internal consistency ($\alpha = 0.919$), other Cronbach's alphas were marginally inferior (second iteration: $\alpha = 0.918$; third iteration: $\alpha = 0.912$; fourth iteration: $\alpha = 0.916$). Other possible arrangements oversaw all iterations during reliability analysis by selecting *descriptives for scale if item deleted* option in SPSS. Out of multiple paths, none of them downscaled CCA internal consistency nor altered significantly mean values, variance and Pearson correlation coefficient (r) (see Table 2 for all iterations and possibilities if specific items were deleted). Triangulating outputs from second factorial analysis with 4-iteration reliability analysis resulted in a final decision of removing items 22 and 23 from CCA.

Factor	Version	Item	If excluded variation				Final α
			$\bar{x}$	Variance	r	α	
CCA	1	21	25.57	22.15	0.749	0.898	0.919
		22	25.44	22.31	0.601	0.916	
		23	25.46	21.52	0.791	0.893	
		24	25.51	21.86	0.743	0.898	
		25	25.40	22.25	0.731	0.899	
		26	25.59	22.30	0.721	0.900	
		27	25.37	22.19	0.837	0.890	
		28	25.57	22.15	0.749	0.898	
	2	21	25.6075	21.008	0.756	0.905	0.918
		22	25.4423	22.315	0.645	0.916	
		24	25.4956	20.546	0.779	0.902	
		25	25.5488	20.721	0.750	0.905	
		26	25.4334	21.200	0.726	0.908	
		27	25.6270	21.131	0.732	0.907	
		28	25.4067	21.018	0.851	0.896	
	3	21	25.57	22.15	0.749	0.898	0.912
		23	25.44	22.31	0.601	0.916	
		25	25.46	21.52	0.791	0.893	
		26	25.51	21.86	0.743	0.898	
		27	25.40	22.25	0.731	0.899	
		28	25.59	22.30	0.721	0.900	
	Final	21	21.29	15.77	0.762	0.900	0.916
		25	21.18	15.40	0.780	0.898	
		26	21.23	15.58	0.747	0.903	
		27	21.12	16.06	0.711	0.907	
		28	21.31	15.85	0.741	0.903	

Table 2. Weighting different factor arrangements for Climate Change Awareness (CCA) while controlling for Cronbach's alpha (α) mean ($\bar{x}$), variance, and Person correlation coefficient (r) discrepancies. Calculations were made with SPSS version 29.0.0.0 (241). Abbreviation refers to Climate Change Awareness (CCA) factor.

Instrument 4-factor 22-item version demonstrated robust psychometric performance. AD factor loadings ranged from 0.553 to 0.733. Item-item correlations in AD were moderately strong, unidirectional, from $r = 0.243$ up to $r = 0.576$, and significant ($p < 0.0001$). Moreover, item-item correlations stood significant within bivariate parameters and $CI = 95\%$. Correlation robustness continued under Kendall's tau-b and Spearman's rho in direction and significance ($p < 0.0001$). Residuals exhibit non-redundancy of 93.0% for a $CI = 95.0\%$. Similarly, factor loadings of CSA (0.336-0.761), SCB (0.710-0.776) and CCA (0.743-0.852) delivered good psychometric performance. Correlation tests followed with congruent results for CSA ($0.234 \leq r \leq 0.526$ $p < 0.0001$), SCB ($0.333 \leq r \leq 0.456$ $p < 0.0001$) and CCA ($0.542 \leq r \leq 0.761$ $p < 0.0001$), and residuals demonstrated non-redundant outputs for CSA (80.0%),

SCB (100.0%) and CCA (73.0%) for a CI=95%. Successive back-and-forths during factorial analysis polished the scale until its optimal version (see Table 3 for a rotative component matrix and antecedent steps).

Item		Component				
Initial version	After Factorial Analysis	1	2	3	4	5
1	AD-1	-0.003	0.683	-0.086	0.071	-0.113
2	Remove	-0.010	0.616	0.098	-0.175	0.031
3	AD-2	-0.122	0.540	-0.192	-0.089	0.022
4	Removed	0.005	0.478	0.200	0.212	-0.098
5	AD-3	-0.039	0.693	0.059	0.032	-0.013
6	AD-4	-0.308	0.652	-0.103	0.121	0.069
7	AD-5	-0.054	0.642	0.036	0.124	0.156
8	Removed	-0.026	0.491	0.027	0.370	-0.371
9	AD-6	-0.203	0.693	-0.174	0.128	0.053
Component load		-0.759	5.488	-0.134	0.795	-0.264
10	CSA-1	0.172	0.033	0.283	0.720	0.074
11	CSA-2	0.042	0.094	0.210	0.752	0.221
12	CSA-3	0.149	0.569	0.183	0.250	0.051
13	CSA-4	0.155	0.354	0.150	0.526	-0.116
16	CSA-5	0.224	0.171	0.250	0.640	-0.070
Component load		0.741	1.221	1.076	2.887	0.160
14	SCB-1	0.236	-0.016	0.613	0.128	0.024
15	SCB-2	0.113	0.028	0.637	0.274	0.160
17	SCB-3	0.240	0.028	0.659	0.094	0.071
18	SCB-4	0.281	-0.010	0.697	0.107	0.041
19	Remove	0.328	-0.044	0.559	0.289	0.081
20	SCB-5	0.309	0.033	0.674	0.163	-0.037
Component load		1.507	0.019	3.839	1.055	0.340
21	CCA-1	0.752	-0.042	0.183	0.182	0.233
22	Removed	0.696	-0.064	0.242	0.113	-0.077
23	Removed	0.668	-0.070	0.279	0.001	-0.161
24	CCA-2	0.808	-0.080	0.228	-0.001	0.104
25	CCA-3	0.805	-0.013	0.111	0.077	0.126
26	CCA-4	0.745	-0.142	0.282	0.059	-0.064
27	CCA-5	0.749	-0.071	0.125	0.164	0.159
28	CCA-6	0.845	-0.112	0.194	0.109	0.091
Component load		4.705	-0.461	1.124	0.589	0.649

Table 3. Rotative component matrix. These coefficients correspond to principal component rotative component matrix results with *varimax* rotative extraction method computed in SPSS version 29.0.0.0 (241). Cell colors make allusive representations of each component correspond to each factor. Abbreviations refer to Action Denial (AD-n), Climate Science Awareness (CSA-n), Scientific Consensus Beliefs (SCB-n) and Climate Change Awareness (CCA-n) items.

3.1.4. Scale final version

The final version of the scale includes six items for quantifying AD, five focused on CSA, five about SCB and six about CCA. Calculating again Cronbach's alphas for the 4-factor 22-item version corroborates instrument internal consistency by yielding good consistency in AD ($\alpha = 0.787$), CS ($\alpha = 0.748$), and SC ($\alpha = 0.816$) and excelling in CC ($\alpha = 0.916$), following Taber (2018) classification. The 4-factor 22-item scale delivered a 59.4% of cumulative capture through rotative square loadings sums by the fourth component (significantly above previously calculated capture of 51.5%). Holding these results proves how crucial factorial scrutiny was to end up with an optimal version with 4 factors and 22 items (Table 4).

Factor	Code	Item	α
AD	AD-1	It's prudent to wait for the results of more research before we reduce our nation's greenhouse gas emissions.	0.787
	AD-2	Overall, trying to reduce our nation's greenhouse gas emissions will be bad for our nation.	
	AD-3	Individual and public investment in climate change mitigation will weaken human prosperity.	
	AD-4	Climate change is not a problem yet, it is merely a possible risk.	
	AD-5	Most of the products, goods, and services which we consume and acquire are already very sustainable, their own campaigns show it clearly.	
	AD-6	If we continue to increase the world economy, we won't need to worry about climate change.	
CSA	CSA-1	I trust the things that scientists say about climate change.	0.748
	CSA-2	Climate scientists are sincere in their research into climate.	
	CSA-3	Research that challenges the mainstream point of view is given honest treatment by the scientific community.	
	CSA-4	Scientists who challenge the mainstream view of climate change present an honest treatment of the scientific evidence.	
	CSA-5	The process by which scientific papers are peer-reviewed and published is reliable.	
SCB	SCB-1	Many scientists believe that the climate is changing.	0.816
	SCB-2	The scientific evidence that the climate is changing due to human activities is very solid.	
	SCB-3	Humans are significant to have an appreciable impact on global temperature.	
	SCB-4	Human CO ₂ emissions cause climate change.	
	SCB-5	Most of the warming over the last 50 years is due to the increase in greenhouse gas concentrations.	
CCA	CCA-1	Over the last 50 years, the Earth's climate has been changing very quickly.	0.916
	CCA-2	Climate change is and will be a problem for Portugal.	
	CCA-3	Climate change is and will be a problem for me and my family.	
	CCA-4	Climate change is and will be a problem for other species of animals and plants and for the environment.	
	CCA-5	Over the next 50 years, the Earth's climate will change very quickly.	
	CCA-6	Human health will be affected by the rising temperature.	

Table 4. Reliability results for 4-factor 22-item scale tier by calculating Cronbach's alpha (α) with SPSS version 29.0.0.0 (241). Abbreviations refer to Action Denial (AD), Climate Science Awareness (CSA), Scientific Consensus Beliefs (SCB) and Climate Change Awareness (CCA) factors.

3.2. Attitudes toward climate change and action denial (RQ₂₋₃)

Climate change attitudes are among the most extensively quantified psychological dispositions (Dunlap et al., 2002; Fasce et al., 2023). But, evidence of core attitudes behind climate change denial is rare (Cook, 2020; Damico et al., 2023). Although attitudes are not direct predictors of action, positive attitudes appear among the strongest predictors of support for mitigation policies and behaviors (Dunlap et al., 2002; Kulin et al., 2021).

3.2.1. Normality

Hereafter, only the 4-factor 22-item version of the scale receives attention. After factorial adjustments, normality needed to be reassessed. Once again, individual items and mean scalar variables obeyed univariate normal distribution with K-S test ($p < 0.0001$ CI=95%) and Monte Carlo's parameters of significance ($p < 0.0001$ CI=95%). H_0 gets rejected hence statistical parametric inference produces suitable results (Marôco, 2021).

3.2.2. Descriptives and correlations

Means and standard deviation (SD) values indicate that participants show satisfactory levels of CSA, higher SCB and even greater CSA. AD mean stayed below mid-range, thereby below it deserved a clear explanation (Table 5).

Factors	$\bar{x}$ (SD)	AD	CSA	SCB	CCA
AD	2.29 (0.789)	1	0.304*	-0.117**	-0.247*
CSA	3.34 (0.638)		1	0.515*	0.325*
SCB	4.07 (0.764)			1	0.551*
CCA	4.24 (0.788)				1

Table 5. Correlation matrix with bivariate parameters calculated with SPSS version 29.0.0.0 (241). Abbreviations refer to Action Denial (AD), Climate Science Awareness (CSA), Scientific Consensus Beliefs (SCB) and Climate Change Awareness (CCA) factors. * $p < 0.001$ ** $p < 0.01$

In addition, AD correlates negatively with significance to SCB ($r = -0.117$ $p < 0.01$) and CCA ($r = -0.247$ $p < 0.001$). At the same time, AD co-occurs positively with CSA ($r = 0.304$ $p < 0.001$). Other attitudinal controlling variables correlate positively to one another with moderate intensity. All follows Mills and Gay (2019) classification.

3.2.3. Linear regressions

While Pearson correlations point the direction and intensity of relations between variables (Marôco, 2021; Mills & Gay, 2019), linear regressions render further conclusions on their

interplay. Controlling variables were undertaken through linear regression tests under a CI=95% with *enter* method. Models show how CSA (Model #1), SCB (Model #2) and CCA (Model #3) predict action denial based on slopes (b). Model adequacy was evaluated through the coefficient of determination (R^2) and plotting standardized residuals (Figure 12).

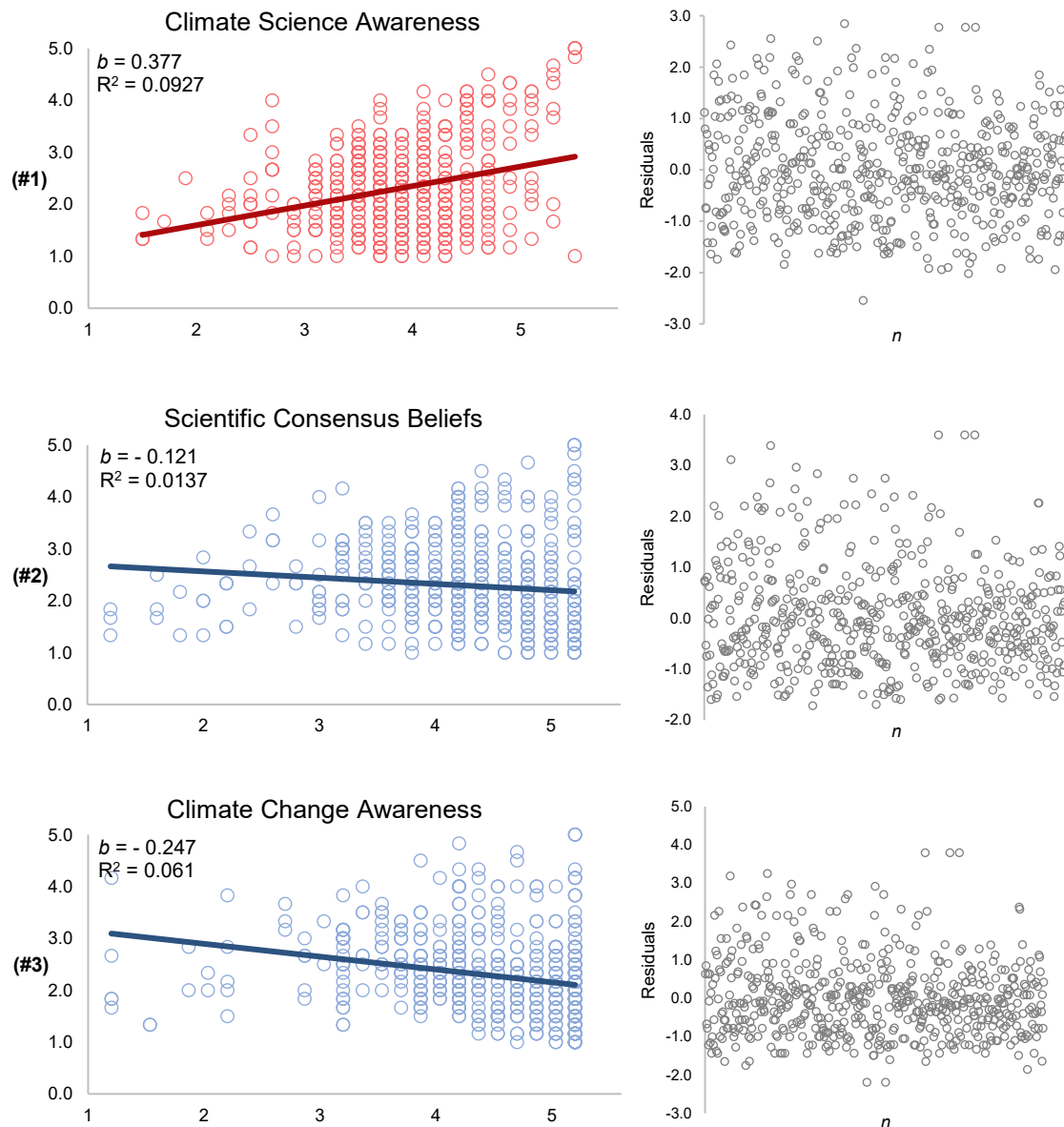


Figure 12. Linear regression models with *enter* method from SPSS version 29.0.0.0 (241) under a CI=95% and degrees of freedom: $df=1$. On the left, plots exhibit Climate Science Awareness (Model #1), Scientific Consensus Beliefs (Model #2), and Climate Change Awareness (Model #3) predicting Action Denial. On the right, Standardized Residuals plots with diffuse placement give cues about models' suitability.

Model #1 traces a positive slope with $f(x) = 0.377x + 1.034$ within the adjustment $R^2 = 0.0927$. It can be summarized into $b = 0.377$, $\beta = 0.304$, $OR = 0.752$, $SE = 0.050$, $t = 57.186$, $p < 0.0001$. Model #2 twists into a negative slope with $f(x) = -0.121x + 2.783$ carrying the adjustment of $R^2 = 0.0137$, with other details such as $b = -0.121$, $\beta = -0.117$, $OR = 0.784$, $SE = 0.043$, $t = 15.516$, $p < 0.0001$. Model #3 also observes a negative trend from $f(x) = -$

$0.2474x + 3.3407$ with greater adjustment of $R^2 = 0.0611$. Summarized as follows $b = -0.121$, $\beta = -0.117$, $OR = 0.784$, $SE = 0.043$, $t = 15.516$, $p < 0.0001$.

3.2.4. Sociodemographic analysis

Science denial occurs predominantly in specific sociodemographic profiles. Science denial appears more frequently among right-wing or conservative and religious individuals (Fasce et al., 2021; Fraembs & Drobnič, 2024; Hart & Nisbet, 2012; Kulin et al., 2021; Lewandowsky & Oberauer, 2016; McCright et al., 2016).

Instrument collected data about ten sociodemographic variables. Two of them yielded results to look up for. Pearson correlations saw significant positive coefficients between AD and politics ($r = 0.182$ $p < 0.0001$), similar to AD and religion ($r = 0.151$ $p < 0.0001$). Politics correlated negatively to SCB ($r = -0.103$ $p = 0.015$) and CCA ($r = -0.170$ $p < 0.0001$).

Handling these results suggested conducting regression models controlling for politics and religion as predictors of action denial. Politics is an ordinal variable, therefore, it could be undertaken through linear regression (following Marôco, 2021). Politics model verified a positive slope throughout the political spectrum (Table 6).

Politics model				
R	R ²	R ² _{adj}	OR	
0.182	0.0331	0.0313	0.776	
ANOVA				
	SS	gl	MS	F
Regression	11.559	1	11.559	19.185**
Residuals	337.416	560	0.603	
Coefficient				
	<i>b</i>	SE	β	<i>t</i>
Politics	0.164	0.037	0.182	4.380*

Table 6. Summary of the linear regression model conducted with *enter* method for total sample size ($n = 562$) within a CI=95% computed with SPSS version 29.0.0.0 (241). Politics was the independent variable, and AD was the dependent variable or predictor. * $p < 0.0001$ ** $p < 0.001$

Similar to previous models, plotting residuals supported Politics model linearity assumptions. Religion, on the other hand, is a nominal variable with dummy treatment. Hence, categorical regression is more suitable (Marôco, 2021). After initial recognition, AD occupied the dependent variable place while considering religion an independent variable. Categorical regression pictured a nuanced positive tendency for AD-religion interaction ($b = 0.152$) (Table 7). Notwithstanding, plotting standardized residuals displays higher density, which is congruent with religion nominal characteristics. Religion model did not meet any conclusive outputs (see Table 7 for categorical regression results)

Religion model				
R	R ²	R ² _{adj}	OR	
0.152	0.0231	0.0214	0.977	
ANOVA				
	SS	gl	MS	<i>F</i>
Regression	12.949	1	12.949	13.208*
Residuals	547.051	558	0.980	
Coefficient				
	<i>b</i>	SE	gl	<i>T</i>
Religion	0.152	0.041	1	13.551*

Table 7. Summary of categorical regression conducted for a total sample of $n = 560$ within a CI=95% computed with SPSS version 29.0.0.0 (241). Religion, independent variable, was treated as non-religious = 0 and religious = 1. Religion discretization saw with *grouping* method two separate groups. AD, dependent variable, conserved its numerical classification with unspecific discretization. * $p < 0.0001$

3.3. Quantifying action deniers (RQ₄)

Up to this point, the reader could envisage that action deniers are not so frequent after all. Quantifying action deniers, however, calls for establishing one or more reference values. Participants whose AD mean scores exceed reference values integrate the action deniers profile.

3.3.1. Looking for a method to quantify action deniers

No established method was found in literature for identifying action deniers using quantitative psychological data. Here, two methods are proposed based on the same methodology that rely on distinct reference values (or baselines). Median method summed AD median (Med) with standard deviation while mean method added mean to standard deviation ($\text{Med}_{\text{AD}} + \text{SD}_{\text{AD}} = 2.96$ and $\bar{x}_{\text{AD}} + \text{SD}_{\text{AD}} = 3.08$).

Mean method quantified 86 action deniers, which represents 15.3% of the total sample ($n = 562$). On the other hand, median method visualized 107 deniers, representing 19.0% of the total sample of $n = 562$.

Attitudes differ in deniers and non-deniers profiles (Figure 13); deniers show higher CSA than non-deniers with mean ($\bar{x} = 3.83$; $\text{SD} = 0.67$) and median methods ($\bar{x} = 3.70$; $\text{SD} = 0.67$), which becomes clear with explanations below. Appears that non-deniers have similar mean scores of SCB using mean method ($\bar{x} = 4.07$; $\text{SD} = 0.78$) and median method ($\bar{x} = 4.09$; $\text{SD} = 0.78$) compared to action deniers. Moreover, non-deniers exhibit clearly higher CCA with mean ($\bar{x} = 4.28$; $\text{SD} = 0.78$) and median methods ($\bar{x} = 4.32$; $\text{SD} = 0.77$) than action deniers.

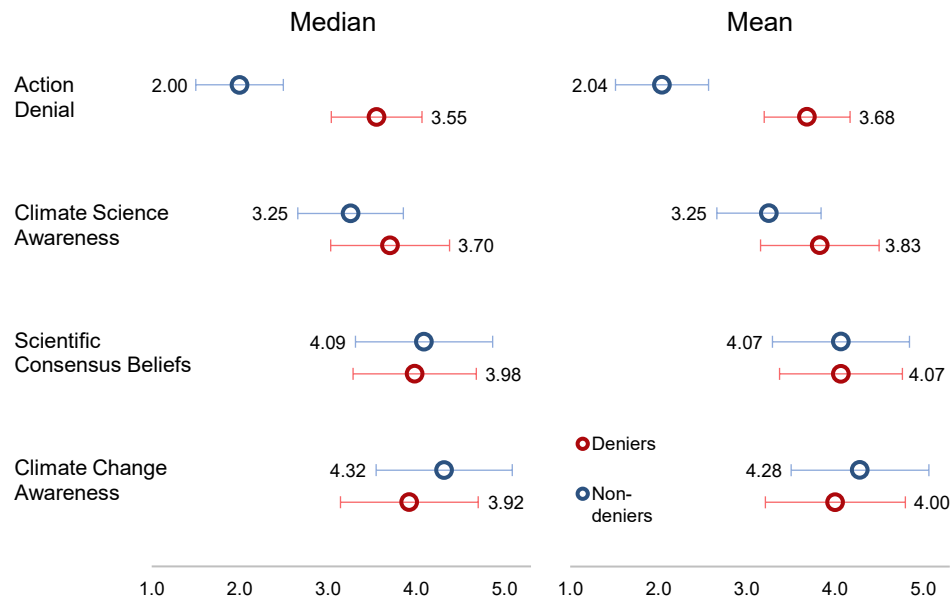


Figure 13. Comparative mean values (circumferences) and SD values (segments) of deniers (coloured in red) and non-deniers (coloured in blue) with median and mean methods. Descriptives were computed with SPSS version 30.0.0.0 (172).

3.3.2. Sensitivity of methods

Discrepancies recommend conducting a sensitivity assessment (S). Sensitivity prove to be unilastic for AD ($S_{Med} = 0.945$; $S_{\bar{x}} = 1.058$), acceptable for CSA ($S_{Med} = 0.778$; $S_{\bar{x}} = 1.285$) and CCA ($S_{Med} = 1.414$; $S_{\bar{x}} = 0.707$), but widely inelastic in SCB case ($S_{Med} = -493.9$; $S_{\bar{x}} = -0.00202$). Overall sensitivity displayed unilastic properties for mean method ($S_{\bar{x}} = 0.762$) while median method had inelastic behavior ($S_{Med} = -123.4$), suggesting that mean method is stable for quantifying action deniers from quantitative psychological data. Henceforth, both methods can be rescued still median method inelastic properties need to be considered.

3.3.3. Quantifying action deniers

Based on both methods, action deniers best estimates are between 15.3% and 19.0% of a total sample of $n = 562$. Though these baselines are exclusive to this data set, methods can be applied broadly in psychology research while always backed up by sensitivity assessments.

3.4. Understanding climate change and action denial (RQ₅₋₈)

Attitude formation and correction have a cognitive dimension too (Campbell, 1963; Eagly, 1992; Ecker et al., 2022). Scholars argue that public concern evolved differently from climate literacy in Portugal (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000). Public survey research faces an epistemic constraint by prioritizing closed-ended

questions over open-ended questions (Bauer & Falade, 2021; Ecker et al., 2022). Neglecting open-ended questions may overestimate public understanding. Mixed-methods approaches can deliver more nuanced and granular assessments in psychology (Coutinho, 2014). Beyond knowledge appraisal, investigation sought to understand how knowledge-related variables interfere with action denial psychological presence.

3.4.1. Measuring understanding of climate change

To minimize overestimating understanding, two open-ended questions gathered data from three knowledge-related variables, specifically understanding of climate action essentials, understanding of climate science essentials on causes and understanding of climate science essentials on consequences. Knowledge valuation drilled public understanding in Fail = 0, Insufficient = 1, Average = 2 and Good = 3 correct entries.

Classifications of understanding of action essentials got fewer insufficient grades than knowledge of causes and consequences. While 42.5% of this general audience showed insufficient knowledge of action, about 56.9% were uninformed of what causes climate change and 61.4% did not meet average requirements for understanding climate change consequences. Notwithstanding, overall percentage of good grades did not vary substantially across variables, registering 26.0% on action essentials, 26.2% on causes and 23.7% on consequences (see Figure 14 for classifications of the total sample). Level of understanding is consistent with expert warnings of a climate illiterate society (e.g., Carvalho et al., 2013).

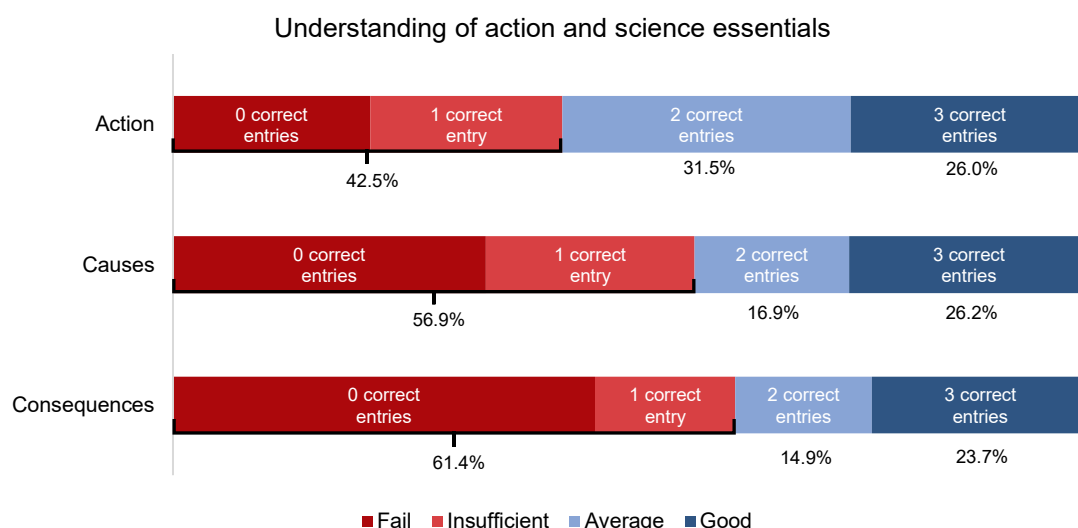


Figure 14. Understanding of action and science essentials estimation for $n = 562$. Evaluation followed pre-defined criteria described in [procedure of understanding climate change and action denial](#) sub-sub-section.

During evaluation, two latent variables popped up. A handful of descriptors collected most of the total entries. At the same time, general audience opinion had multiple misrepresentations of climate science essentials. All forms of denial are misrepresentations of reality, e.g., science denial emerges from unscientific allegations spread through deceiving rhetorical strategies (Cook, 2020; Mendy et al., 2024). Further light exposed associations between these latent variables and other variables, including action denial.

3.4.2. Gateway response effect

Content analysis is part of mixed-methods analysis (Coutinho, 2014). Climate science content was examined under a list of [pre-defined descriptors](#). Climate action content characteristics do not cope with restrictive criteria; almost any action can be considered climate action still only a few can significantly reduce emissions. Other parameters are described [here](#).

Waste-related descriptors dominate amid data about action essentials; 43.8% of all descriptors are waste-related actions, with recycling collecting over 26.7% of them. Therelike, pollution descriptors correspond to 17.2% of total descriptors in data on causes, followed by deforestation with 14.9%. In contrast, data on consequences did not call attention to a particular descriptor. Additionally, data on understanding of consequences received an inferior number of total entries compared to data focused on understanding of action and causes. Total entries of consequences make up 67.4% of action entries and 75.9% of causes respective entries.

Combining frequencies of descriptors (Table 8) with knowledge valuation and content itself led us to propose the gateway response effect that explains general audience preference for specific descriptors and tapered knowledge about climate change causes and consequences. Gateway response effect is a series of cognitive processes that help individuals meet minimum requirements with the least effort. Heuristics are mental shortcuts in decision-making processes (Ecker et al., 2022). Gateway response effect acts similarly to heuristics in information-recalling processes. It aims to protect intra- and interpersonal credibility by using mental shortcuts for delivering information. Despite producing biased and oversimplified messages, the gateway response effect makes receiving new knowledge less appealing by securing minimum requirements and avoiding cognitive dissonant moments.

Action essentials		
Category	Sub-category	<i>n</i>
Waste	Recycling	250
	Quit smoking	12

	Reutilization, refurbishing, and second-hand purchases	47
	Waste disposal and management	75
	Generate less waste/avoid plastic and food waste	26
Consumption	Responsible consumption	8
	Reduce aerosols (spray, ...)	126
Energy	Housing (thermal comfort, energy efficiency, appliances, ...)	124
	Reduce energy use	39
	Invest in renewable energies	4
	Electric vehicles	5
Transportation	Public transportation (including sustainable transportation)	18
	Walking or biking (including avoiding motor combustion vehicles)	28
Food	Sustainable food consumption	37
Beliefs	Learning and educating about climate change	89
	Climate change awareness	31
	Activism and advocacy (planting a tree, plogging, ...)	12
Miscellaneous	Other (3 less traveling; 3 avoid using paper)	6
Science essentials (causes)		
Needs	Housing	2
	Food consumption (or food waste habits)	54
	Transportation	55
	Resource-dependent economy	17
Means	Energy use (direct or indirect)	14
	Industry	81
	Deforestation	124
	Consumerism and resource consumption	104
	Altering ecosystems	18
	Fossil fuels	69
Endings	GHGs emission	66
	Pollution	143
	Social or economic inequalities	2
	War and conflict	9
	Overpopulation	9
	Waste (recycling, reuse, ...; not including throwing garbage away)	30
Climatic feedback	Greenhouse effect	14
	Albedo-related appropriate articulately	2
Beliefs	Lack of awareness	10
Miscellaneous	Travel	2
	Other	8
Science essentials (consequences)		
Climatic feedback	Global warming	65
	Extreme weather events	73

	Increase mean temperature	77
	More climatic uncertainty	26
	Heatwaves	10
	Drought and desertification	33
	Ocean temperature rise	5
Cryosphere	Thawn	60
	Sea level rise	69
Ecosystems functions	Loss of biodiversity	76
	Water scarcity	23
	Soil loss	3
	Loss of nature's contributions to people	23
	Wildfires	30
	Loss of coral reefs	2
Human systems	Food insecurity	16
	Social instability and conflict	6
	Migration	4
	Health problems and Zoonotic diseases	20
	Affecting indigenous communities	1
Miscellaneous	Other	10

Table 8. Quantification descriptors from data of understanding action and science essentials (causes and consequences).

3.4.3. Misrepresentations of climate science

Content analysis revealed alternative beliefs from participants' perceptions. In most cases, those beliefs amount to misrepresentations of climate science that emerged from inaccurate understanding of scientific concepts. Misrepresenting science can be more problematic than making mental shortcuts through the gateway response effect (Weber & Stern, 2011). Disseminating messages of misaligned science with the *scientific fact seal* is a way of misinforming people, whether voluntarily or not. Corrective interventions are often more challenging than constructing or nurturing accurate representations of science (Cook, 2020; Ecker et al., 2022; Hart & Nisbet, 2012; Kutney, 2024).

Misperceptions were classified into seventeen overarching false beliefs that compiled their core erroneous stressors. Quantification of the frequency of misrepresentations grouped them into one of seventeen overarching misrepresentations. More than one-quarter of participants had at least one measurable misperception about climate science, a total of 159 participants representing 28.3% of the total sample of $n = 562$. The most frequent misaligned *scientific contents* start with misrepresenting ozone layer depletion, microplastics, ocean, water and soil pollution. While some false beliefs stress inadequate appropriation of scientific concepts, others revealed that general audience falls short in

cognitive skills (like OECD, 2024 reports). More information can be drawn from a full description of analytic assumptions behind those seventeen misrepresentations of climate science (Table 9).

Misrepresentations	Analytic assumption	<i>n</i>
<i>Pollution is a consequence</i>	Pollution was valid whenever integrating causes. Thermal pollution was dismissed.	17
<i>Wildfires are causing climate change</i>	Normal wildfires exist as a self-regulating characteristic of the Mediterranean region, though wildfire frequency and severity are amplified by anthropogenic climate change (ACC) (IPCC, 2023).	10
<i>ACC increases earthquake frequency</i>	No clear evidence demonstrates that climate change may alter earthquakes' frequency (Gualandi et al., 2020).	6
<i>Global warming is a cause</i>	Global warming is a consequence (Chen et al., 2021).	10
<i>The greenhouse effect is a consequence</i>	The greenhouse effect is a cause (Chen et al., 2021).	7
<i>Acid rain is a cause or consequence</i>	Acid rain occurs due to high concentrations of sulfurous and nitric oxides. In a broad sense, they are greenhouse gases (GHGs), however, acid rain per se is not a cause or consequence of ACC. But, a byproduct of chemical reactions between gases and water. Although heat catalyzes chemical reactions (United States Environmental Protection Agency, 2024).	4
<i>Microplastics and ocean pollution</i>	In spite of, healthy oceans and water bodies may serve as efficient carbon sinks (IPCC, 2023), the public failed to demonstrate systems thinking by not being able to underscore relations between climate change, ocean and pollution.	38
<i>Water pollution is a cause</i>		22
<i>Soil pollution or incorrect waste disposal are causes</i>	Soil pollution does not necessarily release direct GHGs. Decomposition of organic matter releases CH ₄ (Ritchie et al., 2020). Poor waste management and incorrect disposal are observed in a myriad of waste that does not contribute directly to GHGs concentrations.	26
<i>Sound pollution is a cause/consequence</i>	Sound pollution affects public health with little direct impact on ACC (World Health Organization, 2025). Respondents never mentioned any interaction between sound pollution, biodiversity loss and less carbon sequestration.	5
<i>GHGs are consequences</i>	GHGs concentrations bolster the greenhouse effect that led to ACC (Chen et al., 2021). So, in logical terms, they are not a consequence.	3
<i>Using water is a cause</i>	Although water bodies may interfere with climate, using water per se is not an inducer of change in what we reckon to be climate change.	15
<i>GHGs do not affect air quality or the respiratory system</i>	Some air pollutants influence the climate system, e.g., CH ₄ favors tropospheric ozone (Future Earth et al., 2024), which can create severe health problems (World Health Organization, 2025). At present concentrations, CO ₂ has highest accountability. It does not affect air quality and respiratory systems directly. Respondents failed to properly explain their point.	16
<i>Ozone layer depletion is a cause or consequence</i>	Chlorofluorocarbons (CFCs) breached a hole in ozone layer. Although CFCs (and other halons) can affect the climate system, they have not significantly contributed to temperature anomaly (National Aeronautics and Space Administration, 2025).	41
<i>Atmospheric oxygen depletion</i>	Until today, oxygen concentrations remain without significant oscillations. Nevertheless, ACC alters ocean circulatory dynamics linked to ocean hypoxia and oxygen production (Chan et al., 2025).	8
<i>Smoking</i>	Smoking is a health risk factor with a great impact on human well-being, and producing tobacco has an environmental impact (World Health Organization, 2022). Nonetheless, the exhaled air from smoking does not release GHGs in a significant amount.	3

Others	Participants answered that “waterborne disease”, “space debris”, and “visual pollution” were consequences of ACC, while others failed to distinguish causes from consequences.	6
TOTAL		237

Table 9. Quantification of misrepresentations of climate science amidst knowledge-related variables data. Misperceptions were quantified based on partially or entirely showing content similarities according to an analytical assumption.

Inaccuracies co-occur negatively with AD according to correlation tests within a CI=95%, either to Pearson’s ($r = -0.118$ $p < 0.005$), Kendall’s ($\tau = -0.109$ $p < 0.002$) or Spearman’s coefficients ($\rho = -0.135$ $p < 0.001$). Together demonstrate fragile systems thinking, e.g., take the answers that claim that “the three causes are thaw, floods and deforestation”. Many participants failed to distinguish causes from consequences showing low understanding and lack of systems thinking simultaneously. Many claimed that ozone layer depletion was a cause or a consequence of climate change ($n = 41$ or 7.3% of the total sample). Though NO_2 and fluor gases (e.g., chlorofluorocarbons known as CFCs) have high global warming potential and interfere with ozone layer, their contribution to climate oscillations is marginal compared with CO_2 and CH_4 (Chen et al., 2021; IPCC, 2023).

Another example would be “quit smoking”. Tobacco industry has an ecological footprint. Quit smoking can reduce its associated impact (World Health Organization, 2022). In emission terms, direct emissions from exhaling while smoking, which was what individuals referred to, are insignificant in the total bulk of emissions. Individual emissions can be offset through various actions but avoiding smoking would not represent a significant change, although highly recommended.

3.4.4. Effects of understanding on action denial

Again, all correlation inference tests confirmed that understanding of action correlates negatively to action denial ($r = -0.200$ $p < 0.0001$; $\tau = -0.150$ $p < 0.0001$; $\rho = -0.195$ $p < 0.0001$ CI=95%), in line with logical premises. Likewise, understanding of science essentials co-occurs negatively with action denial, either causes ($r = -0.258$ $p < 0.0001$; $\tau = -0.210$ $p < 0.0001$; $\rho = -0.130$ $p < 0.0001$ CI=95%) or consequences ($r = -0.178$ $p < 0.0001$; $\tau = -0.130$ $p < 0.0001$; $\rho = -0.165$ $p < 0.0001$ CI=95%).

Thereafter, linear regression models were undertaken under a CI=95% while considering action denial as dependent variable and individually computing knowledge-related variables as independent variables. Models of understanding of action essentials (Model #4), causes (Model #5) and consequences (Model #6) extracted valuable information. Linearity adequacy took into account slope (b), adjustment (R^2) and plots of standardized residuals.

Models converged on the same conclusion. Superior understanding spots lower action denial psychological presence (Figure 15).

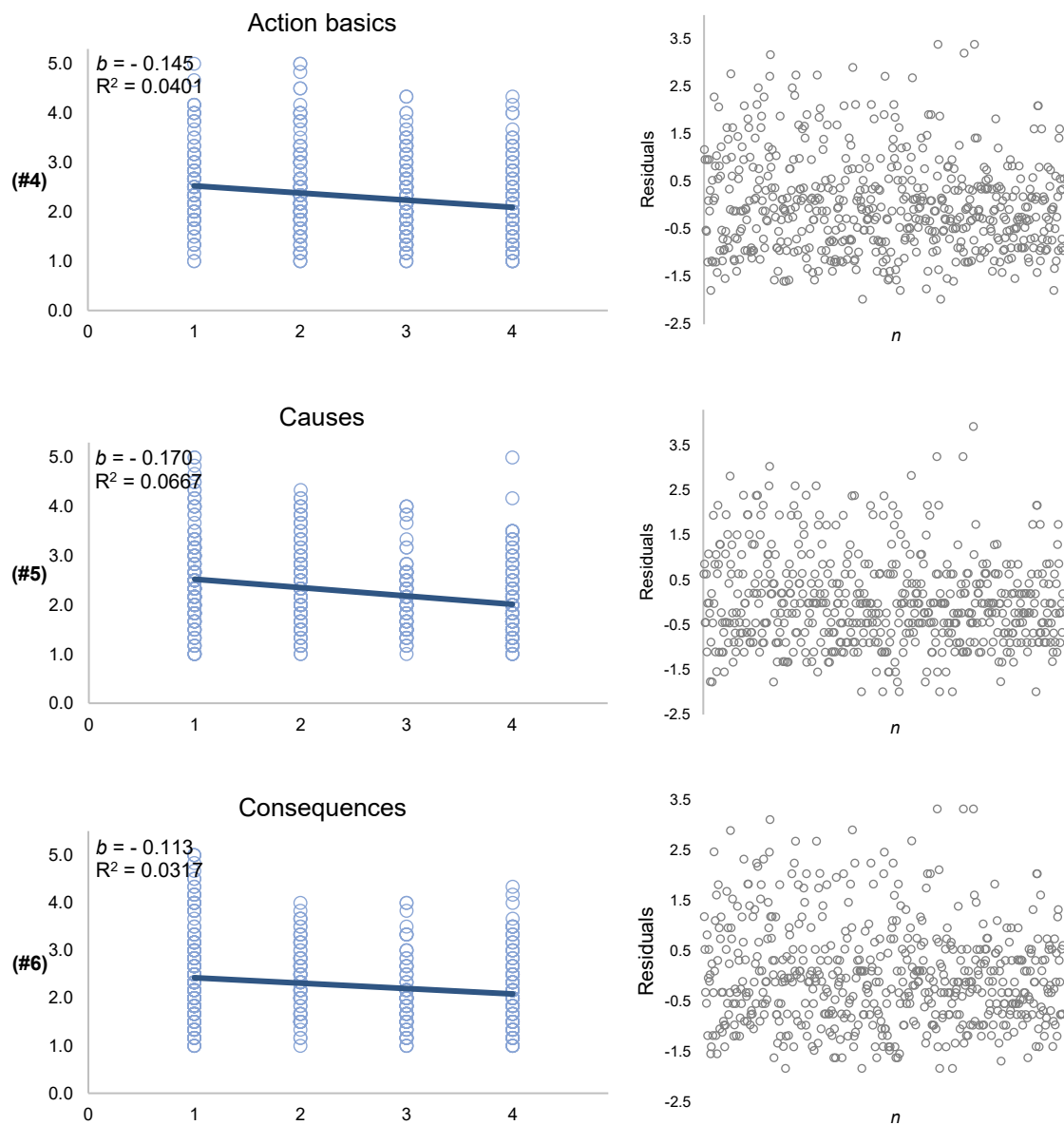


Figure 15. Linear regression models with *enter* method from SPSS version 29.0.0.0 (241) under a CI=95% and degrees of freedom: df=1. On the left, plots display understanding of action essentials (Model #4), understanding of science essentials on causes (Model #5) and understanding of science essentials on consequences (Model #6) models predicting Action Denial. On the right, Standardized Residuals plots with diffuse placement give cues about modeling adequacy.

Model #4 recreates a negative function through $f(x) = -0.145x + 2.671$ adjusted by a $R^2 = 0.0401$. Action essentials model can be summarized into $b = -0.145$, $\beta = -0.200$, $OR = 0.773$, $SE = 0.030$, $t = -4.835$, $p < 0.0001$.

Model #5 follows a negative trend from $f(x) = -0.170 + 2.691$ with a coefficient of determination of $R^2 = 0.0667$. Causes model can be synthesized into $b = -0.170$, $\beta = -0.258$, $OR = 0.763$, $SE = 0.027$, $t = -6.327$, $p < 0.0001$.

Model #6 expresses a similar slope with $f(x) = -0.113 + 2.537$ and $R^2 = 0.0317$ of adjustment. Consequences model is defined by $b = -0.113$, $\beta = -0.178$, $OR = 0.777$, $SE = 0.026$, $t = -4.282$, $p < 0.0001$.

Evidence reinforces that action denial psychological presence falls along higher levels of understanding. Profiling methods for quantifying action deniers can complement that by computing descriptives of knowledge-related variables across profiles. Reassessing method sensitivity (S) yielded relevant overall unilastic properties mean method ($S_{\bar{x}} = 0.749$) and median methods too ($S_{Med} = 0.755$). So, here, both methods produce reliable results (Figure 16).

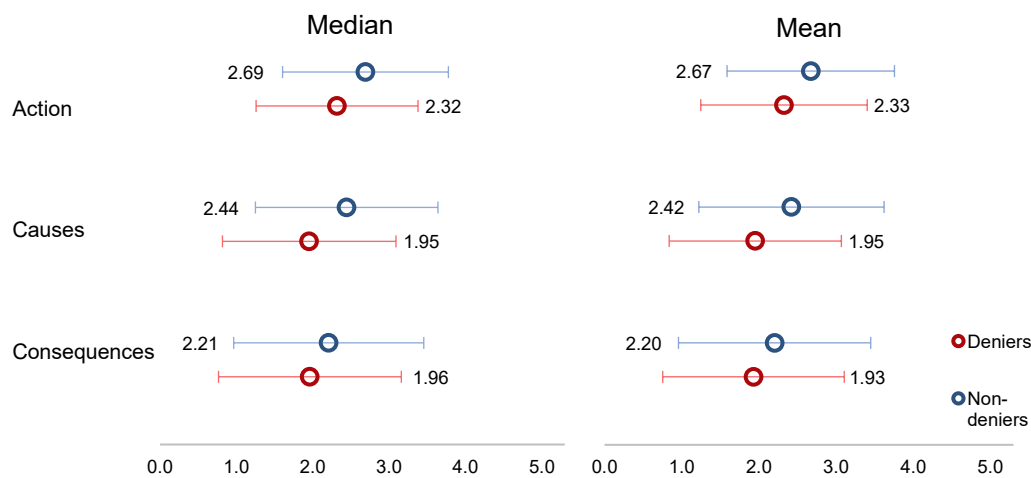


Figure 16. Comparative mean values (circumferences) and standard deviation values (segments) of deniers (coloured in red) and non-deniers (coloured in blue) with median method and mean method on the left and the right, respectively. Descriptives were calculated with SPSS version 30.0.0.0 (172). Sensitivity (S) of median and mean methods $S_{Med} = 0.755$ and $S_{\bar{x}} = 0.749$, respectively.

Profile comparison provided information on how level of understanding relates to action denial. Non-deniers had a more robust understanding of all knowledge-related variables. All results support a reinforcing feedback between lack of understanding and misinformation susceptibility (e.g., Kyrychenko et al., 2025 observed superior misinformation susceptibility among less educated people).

3.4.5. Effects of understanding on other attitudes

A snapshot of how understanding relates to other attitudes made adjacent progress. Climate Science Awareness (CSA) did not collect conclusive results. Notwithstanding, other attitudes prompt valuable insights.

Understanding of action correlates positively with Scientific Consensus Beliefs ($r = 0.147$ $p < 0.001$; $\tau = 0.102$ $p = 0.002$; $\rho = 0.130$ $p = 0.002$ $CI=95\%$) and Climate Change Awareness ($r = 0.144$ $p < 0.001$; $\tau = 0.119$ $p < 0.001$; $\rho = 0.151$ $p < 0.001$ $CI=95\%$). Understanding of

causes also correlates positively to Scientific Consensus Beliefs ($r = 0.127$ $p < 0.003$; $\tau = 0.100$ $p = 0.002$; $\rho = 0.127$ $p < 0.003$ CI=95%) and Climate Change Awareness ($r = 0.125$ $p < 0.003$; $\tau = 0.106$ $p = 0.001$; $\rho = 0.133$ $p < 0.002$ CI=95%). Therelike, understanding of consequences co-occur positively with Scientific Consensus Beliefs ($r = 0.091$ $p = 0.03$; $\tau = 0.061$ $p = 0.066$; $\rho = 0.077$ $p = 0.069$ CI=95%) and Climate Change Awareness ($r = 0.134$ $p = 0.001$; $\tau = 0.070$ $p = 0.036$; $\rho = 0.089$ $p = 0.035$ CI=95%).

Linear regressions found congruent functions to what correlations anticipate. All individual models verified positive slopes undertaking knowledge-related variables as independent variables and attitudes as predictors. Establishing linear models with average for all three knowledge-related variables, charted a positive trend of Scientific Consensus Beliefs ($b = 0.137$ $\beta = 0.160$ $R_2 = 0.025$ $R_2^{\text{adj}} = 0.024$ OR = 0.755 SE = 0.036 $r = 0.160$ $t = 3.823$ $p < 0.001$ CI=95%) and Climate Change Awareness ($b = 0.157$ $\beta = 0.177$ $R_2 = 0.032$ $R_2^{\text{adj}} = 0.030$ OR = 0.776 SE = 0.037 $r = 0.177$ $t = 4.268$ $p < 0.001$ CI=95%) throughout understanding spectrum (average value of all knowledge-related variables treated with ordinal variable parameters from 1 to 4). Residuals maintained a non-continuous standard display in all models assisting model adequacy.

4. Discussion

Shortly after leaving theater premises, denial narratives still echoed. Their biased perspectives and rhetorical strategies caught attention and seem to have a long-lasting effect. Cipher detected action denial during the play. Its cryptographic capture expanded after reprogramming. On the way home, action denial messages popped up from ordinary people conversations. That struck like a lightning bolt. It was time to test on a general audience. There was much work to do; over subsequent months, relentless efforts to capture action denial in a general population have led to the upcoming final discussion.

4.1. On exploring action denial psychological construct

Psychometric scales embodied in instrument collected data on [quantitative variables](#). They were submitted to factorial scrutiny to assess psychometric performance and improve reliability. Factorial analysis is made of back-and-forth steps. Below, light sheds upon the most relevant ones.

Expectations of an orthogonal factorial model between Action Denial (AD) and other attitudes got confirmed by obtaining better factorial modeling with *varimax* extraction ([Table 1](#)). Simultaneously, AD negative factorial loadings across components manifest a correct transference of approaches to a dispositional format ([Table 3](#)). By the end of factorial scrutiny, reliability tests confirm internal consistency for all factors, with AD delivering $\alpha = 0.787$ in its final configuration ([Table 4](#)).

AD deserves more attention. AD final version has six instead of nine items. Items 2, 4, and 8 saw more diffusive factorial weights across rotative component array. Item 2 narrates a misleading frame transferring climate uncertainty approach by phrasing “We have too many problems to deal with to try to reduce our nation’s greenhouse gas emissions.” Eurobarometer saw PT respondents choosing poverty, hunger, lack of drinking water, and economic instability over climate change when asked to rate the most serious global problems (EU, 2023a). Those risk perceptions are consistent with item 2 removal. Eurobarometer data also revealed that Portuguese understanding is lower about climate change and economics (EU, 2023a), i.e., inaction economic impact. Discourse of delay strategy use emphasizing the downsides approach to gaslight climate change economic repercussions (Damico et al., 2023). Item 4 translated emphasizing the downsides approach into a disposition as follows “If we make abrupt consumption shifts socioeconomic problems will emerge and we will never tackle climate change.” Limited understanding of economics behind climate change in Portugal can explain why item 4 saw less reliable results. Item 8 says “Sooner or later scientific and technological evolution will solve climate

change.” The same Eurobarometer data depicts strong beliefs in renewable energy ability to resolve it all (EU, 2023a). Item 8, also retreated from scale final version, consists of a disposition focused on a technological optimism approach by claiming that economic development could ideally figure out a way to reduce environmental impact and inequalities created by leading economies in the first place, a worldview from neoclassical capitalist economics still resident in Portugal. Results of public surveys are consistent with removing items 2,4 and 8. Adding to Portuguese expert concern about a rarefied public understanding (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000), findings verify a knowledge deficit about climate change economics in a general audience.

Overlapping items between Climate Science Awareness (CSA) and Climate Change Awareness (CCA) carried out scientific consensus messages ([Table 1](#)). Thus, it was an opportunity for reevaluating those items extracted from previously valid instruments (Cook et al., 2017; Fasce et al., 2023; McCright et al., 2016). Scientific Consensus Beliefs (SCB), an *ad hoc* factor, had a robust internal consistency ($\alpha = 0.816$; see [Table 4](#)). Science deniers portray effective messages to attack the scientific consensus (Lewandowsky et al., 2013; 2017; Ranney & Clark, 2016). Scientists advocating human accountability (Lynas et al., 2021) led industries to redirect focus from defying scientific consensus to climate delay messages (Rojas et al., 2024). Though people underestimate scientists agreement (Večkalov et al., 2024). Here, SCB renders how participants are psychologically moved to believe in scientific agreement rather than what appears in Večkalov et al. (2024).

Support for Climate Action (SCA) poor performance compared to original results deserves clarification (McCright et al., 2016). Using a shorter version of SCA explains poor factorial performance. Meanwhile, one overlapping item was removed from SCB with a second factorial analysis, while another two items were collapsed by pondering possible CCA versions through reliability tests. All these and other intermediate steps delivered a solid 4-factor 22-item scale with 59.4% of internal capture of the principal components.

4.2. On attitudes toward climate change and action denial

Sampling disables any generalization. Conclusions drawn here and hereafter may or may not picture the Portuguese public but, above all, render good information about a special general audience. Action denial factor (AD) increases at higher levels of Climate Science Awareness (CSA) yet diminishes when Scientific Consensus Beliefs (SCB) and Climate Change Awareness (CCA) ([Table 5](#) and [Figure 12](#)).

AD and CSA psychological interaction is not an impairing relation ($r = 0.304$ $p < 0.001$; $b = 0.377$). Scholars argue that climate countermovements know climate science gold

standards but still make science denial claims making action denial howls sound louder by the day (Oreskes & Conway, 2010; Oreskes, 2004; Rojas et al., 2024; Supran et al., 2023).

Interventional research reported that reinforced scientific consensus beliefs in general audiences yield great results in tackling misinformation impact (Cook et al., 2017; Lewandowsky et al., 2013). Findings fortify those conclusions for an understudied form of denial, action denial. At the same time, underscoring the way for countermeasuring action denial by delivering interventions focused on scientific consensus messages and climate change repercussions, upon which SCB and CCA insisted.

Sociodemographic analysis shows that individuals with conservative or right-oriented political tendencies hold stronger action denial psychological presence ([Table 6](#)), in line with science denial literature (Farrell, 2016; Hart & Nisbet, 2012; Lewandowsky & Oberauer, 2016; McCright & Dunlap, 2000; Schmid & Betsch, 2019). Religiosity is associated with science deniers (Fasce et al., 2023; McCright et al., 2016), though results did not corroborate it for action denial ([Table 7](#)). Other sociodemographic variables did not render solid results.

Climate change became a politicized topic with mediatic coverage of USA politics (Cook, 2017; Dunlap et al., 2016; McCright & Dunlap, 2000). Conservatives and religious people have more dogmatic worldviews and are less active information seekers (Schulz et al., 2020). Conservatives and less educated people (ideally those who seek less information) are more susceptible to misinformation (Kyrychenko et al., 2025). Social media and AI magnify the feedback loop by closing inside of *echo chambers*, social environments created by algorithms that restrict content to one's interests, eliminating any content that defies one's identity. That amplifies confirmation bias while drilling deeper into ideologically biased beliefs (d'I. Treen et al., 2020; Galaz et al., 2025; Martens et al., 2018; UNDP, 2025; van der Ven et al., 2024). Whenever protecting identity, people tend to engage in motivated reasoning (McCright et al., 2016). *Echo chambers* indulge false perceptions about scientific consensus (Večkalov et al., 2024). Individuals incorrectly forecasting peer perceptions downscale policy support and willingness to adopt climate-friendly practices (Andre et al., 2024) while stopping them from discussing climate change (for climate silence research see Geiger & Swim, 2016).

4.3. On quantifying action deniers

Science denial receives most attention from investigators (Biddlestone et al., 2022; Cook, 2020; Fasce et al., 2023; Hart & Nisbet, 2012; McCright et al., 2016; Schmid & Betsch, 2019), leaving action denial psychology understudied. Action denial consists of a set of

cognitive-behavioral processes made deliberately or not for prompting doubt about the need and urgency to mitigate climate change and human agency to deliver effective action

Denial machine is a notorious cabal group united to increase climate apathy by spreading disinformation deliberately but recently it is progressively swapping science denial with action denial (Lamb et al., 2020; Rojas et al., 2024; Supran et al., 2023; Supran & Oreskes, 2021). Studies about climate denial observed a 3% ratio of deniers in Portugal (Froimovici & Hoyer, 2024), albeit oversimplified climate denial psychology.

Widespread efforts from conservatives, think tanks, industries, fossil fuel companies and investors have been postponing behavioral change (Rojas et al., 2024). Expectations were that action denial could be rooted in general audiences. Methods for quantifying action deniers were not found in literature, whereas most papers analyze allegations from denial machine (e.g., Supran & Oreskes, 2021). Two methods, mean and median methods, established reference values upon which participants can be profiled based on quantitative psychological data from Action Denial (AD) individual average scores.

Sensitivity tests examined method elasticity (consult [Sensitivity of methods](#)); mean method confirmed overall unelastic properties while median method stumbled upon Scientific Consensus Beliefs (SCB). SCB graphic of observations depicted a dense group of observations above average that skewed median, thus explaining median method overall inelastic properties. Then, both methods showed overall adequate elasticity later on when applied to profile deniers and non-deniers for knowledge-related variables.

Oversimplifying climate denial can underestimate its psychological presence in general audience surveys. AD scale and an actual methodology observed 15.3-19.0% action deniers in a sample of $n = 562$. In agreement with results from correlation tests and linear regression models ([Table 5](#), [Figure 12](#)), after profiling action deniers and non-deniers, action deniers had superior Climate Science Awareness (CSA) than non-deniers but lower SCB and Climate Change Awareness (CCA) ([Figure 15](#)).

These results cannot be generalized, although together they suggest an underestimation of deniers. Methodology can be applied to other psychology studies with adaptive capacity to cover local, regional and international reference values (e.g., for quantifying EU action deniers). Still, there is much work to do. This is only a step towards an evidence-based approach to quantify deniers accurately.

4.4. On understanding of climate change and action denial

Preference for closed-ended questions can overestimate public knowledge of any scientific subject (Bauer & Falade, 2021). With that in mind, two tailored open-ended questions were tailored to appraise [qualitative variables](#) in a general audience.

In contrast with reports (Delicado et al., 2020; Froimovici & Hoyer, 2024) and in agreement with experts (Carvalho et al., 2013; Horta & Carvalho, 2017; Nave et al., 2000), data showed lack of understanding in a lay population ([Figure 14](#)). Participants failed the most in climate science, even on superficial concepts. Antecedent surveys with different observation instruments verified distinct results through multiple-choice questions (Froimovici & Hoyer, 2024). Therein climate action showed better performance than climate science. Instrument asked first about actions and only then focused on causes and consequences. Data stressing unparalleled results (with those of Froimovici & Hoyer, 2024) give cues of low motivation among participants to approach climate content. Exemplifying their alternative beliefs further supports a large understanding deficit. For instance, anyone saying that “I do not see” [where I can change to reduce my carbon footprint] or “I consume little water in showering, I walk, and I do not smoke.” (as participant #335 asserts), evidences inconsistent understanding of action essential whereas reducing water use and quit smoking hardly translate into a decrease in overall individual direct and indirect emissions.

Limited understanding can deflect human agency to act or, in the first place, recognize the necessity to do so (Kutney, 2024; Lewandowsky, 2021; Ranney & Clark, 2016; van der Linden et al., 2017). Perceiving that action denial grows while understanding decreases is consistent with misinformation cognitive research and interventional investigations. Including, but not exclusively, provides substrate for misinformation influence on perceptions (Cook, 2017; Ecker et al., 2024; Lewandowsky, 2017), sociodemographic profile of deniers (Fasce et al., 2021; Kulin et al., 2021; Kyrychenko et al., 2025; McCright et al., 2016), and misinformation continued influence effect (Ecker et al., 2022; Maertens et al., 2025; Schmid & Betsch, 2019). Furthermore, it agrees with research focused on motivated reasoning (McCright et al., 2016), and dogmatism and information-seeking behaviors (Schulz et al., 2020).

Nonetheless, misinformed people can not be abandoned. These results also stress potential avenues for tailoring interventions, whereas bolstering public understanding of climate science and climate change economics can be supplemented by scientific consensus messages (Lewandowsky et al., 2013) and climate change repercussions frames to narrow the action gap (Ranney & Clark, 2016).

Still about knowledge deficiencies, 28.3% of our sample had at least one misperception or false belief about climate science. Out of seventeen identified misrepresentations of climate science (Table 9), confusion around ozone layer depletion and temperature rise appears on top with 41 observations, followed by ocean, water and soil pollution. Ozone layer and temperature increase are indeed related. CFCs (gases breaching a hole in ozone layer) have a positive radiative forcing effect. Misperceptions of temperature increase due to the hole in ozone layer persist in popular culture (Weber & Stern, 2011), including in Portugal (Froimovici & Hoyer, 2024). If they had notions about GHGs' inventories, they would know that higher concentrations of CO₂, CH₄ and NO₂ are responsible for the current change in climate (IPCC, 2023), not CFCs.

Ocean, freshwater and soil pollution inaccurate beliefs are consistent with their most frequent responses to the climate action question. Lay people think that incorrect solid waste disposal is a source of direct emissions. Despite inadequate waste management having its fair share of accountability (Ritchie et al., 2020; UNEP, 2024), “throwing away garbage”, as participants said, is not a direct source of emissions. Neither avoiding it would reduce individual emissions significantly, albeit it is an eco-friendly behavior.

Another misrepresentation worth discussing is failing to distinguish air pollution from GHGs. Depending on how air pollution is conceptualized, anthropogenic GHGs emissions can be considered to alter normal atmospheric concentrations hence thermally polluting the air. However, air pollution is a public health issue derived from high concentrations of particulate matter, carbon monoxide, tropospheric ozone, sulfur dioxide and NO₂ (WHO, 2024). Unlike GHGs that have positive radiative forcing effects (Chen et al., 2021; IPCC, 2023), particulate matter, carbon monoxide and sulfur dioxide have associated negative radiative forcing effects (Ramaswamy et al., 2018). Moreover, CH₄ catalyzes chemical reactions leading to high ozone concentrations in the troposphere (Future Earth et al., 2024). In spite of all of this, participants did not state those or other relations between air pollutants and GHGs that could demonstrate knowledge about those concepts or cognitive ability to deal with them.

Misrepresentations endorse the gateway response effect proposal, especially inaccuracies related to pollution and incorrect waste disposal. Gateway response effect consists of mental shortcuts to address minimal performance requirements for maintaining cognitive status among their peers and themselves with minimum effort. Gateway response effect was inferred from waste-related descriptors of climate action knowledge-related variables and pollution descriptors of climate causes variable. Objectives behind gateway response effect are similar to those of motivated reasoning (McCright et al., 2016), i.e., protect one's

identity, status, intra- and inter-personal acceptance. Studying the interplay between social media use, information-seeking behaviors and understanding of science while controlling for dogmatic worldviews and group derogation avoidance would be beneficial for diving into the gateway response effect ([Insight 2](#) presents that research idea).

Proficient systems thinkers value nature more while having more eloquent perceptions of scientific consensus and climate risks (Lezak & Thibodeau, 2016). ACC consists of interwoven interactions (Chen et al., 2021); knowledge-related variables (cause and consequences) hide information about participants' systems thinking. Misrepresenting *greenhouse effect as a consequence* instead of a cause is a clear example of fragile conceptual understanding, poor systems thinking or both. Participant #86 said that “the three causes are thaw, floods and deforestation.” Thus, failing to differentiate between causes and consequences, as all entries are consequences (see [Appendix 2](#) for consulting the full list of causes and consequences). Others have fallen into one of those or other misrepresentations of science showing systems thinking underdevelopment.

4.5. Significance

Antecedent theoretical and empirical works on misinformation related to continued influence effect, information-seeking behavior relation to dogmatism and sociodemographic profiles of deniers illustrate a stringent methodology taken here.

Assessing understanding of climate change, attitudes, and action denial breached several potential avenues for future research (see [Insight 1](#) and [Insight 2](#)). Additionally, it unraveled gaps for better weaving tailored science communication and education interventions (see [Conclusion](#)).

The significance of this work lies in investigative outputs. Conceiving one of the first explorations of action denial psychology beyond text and media analysis to layperson psychs and identifying gateway response effect while delivering a methodology for concretely quantifying action deniers hand valuable outputs for researchers and practitioners. It demystified that climate denial was almost extinct in Portugal. Simultaneously, it draws important information about why action denial prevails in general audiences compared to science denial.

4.6. Perspective and insights

4.6.1. Perspective

Climate change is a wicked problem (Incropera, 2015; Rittel & Webber, 1973), demanding individual and collective efforts (e.g., IPCC, 2023). Misinformation is a serious threat (World Economic Forum, 2024); it downgrades public trust in scientific institutions (Ecker et al.,

2022; 2024; Cologna et al., 2024; 2025) and support for climate policy (Andre et al., 2024; Oreskes & Conway, 2010; Supran et al., 2023). Climate science denial influences policymakers' views of science and education effectiveness (Kutney, 2024). Tackling climate change denial demands ceasing misinformation overflowing in social media (on the public side), inoculating everyone against misinformation (all societal agents), correcting misperceptions of science (carried by multiple stakeholders), and, with the same importance, communicating the risk of losing science for Our Common Future (across all sectors).

That was about climate science denial, onto action denial now. International assemblies and conventions can make ambitious pledges; however, subverting their targets in everyday citizen lives requires a norm-value-behaviors shift encompassing climate-friendly practices. Science, education and science communication are Humanity's guardrails to prevent falling from cognitive rollercoasters by keeping norms, values and behaviors adjusted amid a sustainable railroad.

Recently, science in USA is at risk due to budgetary cuts and other restrictions under Trump's administration (Canon et al., 2025; Stockton, 2025). On that Western side of the Atlantic Ocean, lies a conservative government composed of politicians who deliberately spread climate denial during political campaign. Scientists need to step up to defend their job and Humanity's most valuable asset in tackling contemporary and future challenges (Cologna et al., 2024; 2025; Yearley, 2021). Western living standards were possible only by stimulating science, technology and education (Steffen et al., 2011; 2015a). That illustrates scientists' pivotal role in fortifying human well-being, citizens and decision-making.

Portuguese scientists warn about a lack of investment in science and technology (Carvalho et al., 2013). In Portugal, climate science denial does not appear explicitly in political campaigns and debates. Nevertheless, research career precariousness puts science continuity at risk. Disinvesting from science will downscale national resilience to change, institutional competitiveness and jeopardize national ability to overcome challenges, including climate change.

Whereas attitudes progressed rapidly while behaviors and knowledge remained insufficient, sharing recommendations can help avoid falling into a denial ditch. Science communicators, educators, and researchers should establish collaborative bounds to (1) improve instruments reliability for assessing understanding avoiding overestimating understanding, (2) recognize that action denial is a multidimensional psychological construct, so avoid oversimplifying it, (3) when awareness alone fails to optimize climate action, ensure that

science communication and education interventions regularly available for all, (4) strengthen public competencies with special attention to systems thinking and holistic reasoning, (5) monitor interventions attendance and their effect in awareness, understanding and behaviors, (6) develop creative ways to captivate diverse audiences, and (7) reconnect to nature while promoting climate literacy.

4.6.2. Insight 1

Data suggest that action deniers have lower understanding and awareness of scientific consensus and climate change. Analysis and specialized literature end in a cognitive model proposal. The Cognitive Tipping Model (CTM) application overflows science communication and educational research to cognitive science and adjacent domains.

Although researchers argue that the knowledge gap does not affect public decisions (Bauer & Falade, 2021; Bodmer, 1985; Bowater & Yeoman, 2013; Miller, 2004), experts are concerned that those assumptions derive from biased data collected through unreliable instruments that overestimate public actual understanding (Bauer & Falade, 2021; Carvalho et al., 2013; Ecker et al., 2022; Horta & Carvalho, 2017; Nave et al., 2000).

Like any other attitude, action denial weighs differently across participants and intrafactorial measurements (i.e., denialistic techniques and claims). CTM was conceived under positive tipping points theory application to cognitive and behavioral sciences (Powell et al., 2023; other essays on biophysical tipping point in Armstrong McKay et al., 2022; Lenton et al., 2008; 2023), thus, suggesting that awareness, understanding and denial ascribe multidimensional non-linear relations that converge into a tipping point, or more precisely a cognitive tipping interval.

Action denial averages can be inserted in CTM to locate how close people are to falling into the denial ditch or tipping into climate action. CTM is grounded in cognitive misinformation research, including continued influence effect, information-seeking behavior, group derogation avoidance, dogmatism, algorithmic bias, confirmation bias, motivated reasoning, and heuristics. Additionally, CTM helps explain gateway response effect, a series of cognitive shortcuts for minimizing epistemic efforts and yet maintaining inner- and inter-personal cognitive status. CTM also prescribes that for ensuring continued emission reduction, it is necessary to deliver motivational boosters (Maertens et al., 2025), i.e., interventions to prevent the rail from falling below the tipping interval (near to 0,0 in this case) at an individual level (see Figure 17 for an axial representation to exemplify CTM).

More research is required to define and quantify cognitive tipping intervals. Cognitive profiles produce multiple tipping intervals. For instance, conservatives are expected to have

more vertical rails than liberals. Including moderate variables to profile participants would benefit this research agenda. Future research can estimate tipping cognitive intervals, including in the Portuguese population. Then, tailoring interventions and assessing intervention effects would be easier with CTM.

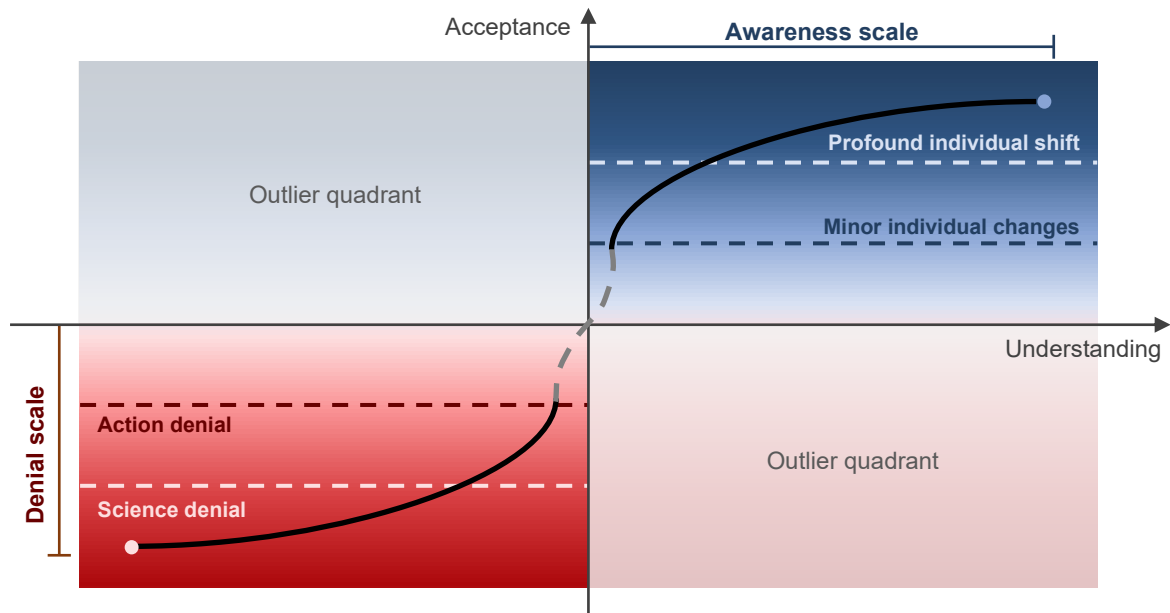


Figure 17. Cognitive tipping model (CTM) exemplified through an axial scheme.

4.6.3. Insight 2

Social media apps are Portuguese's favourite platform for consuming scientific content (Delicado et al., 2020; Mede et al., preprint), and social media is a prolific misinformation environment (Ecker et al., 2024; Hills, 2019; Lewandowsky et al., 2017). Users can share what they think about science, politics and religion on Facebook without their say getting checked before publishing it. This is a double-edged sword; on one hand, freedom of expression is a democratic human right (UN, 2025c), on the other hand, it incubates misinformation and facilitates spreading it.

Digital devices and platforms are impregnated with Artificial Intelligence (AI). Algorithms classify profiles based on interests and hobbies. Unplugging from those pleasant environments where all fragments of information are appealing and everyone seems to care about the same topics erodes interpersonal non-virtual relations. From marketing-oriented to corporate investments, social media platforms dictate market flows nowadays through AI ability to captivate attention and influence behaviors based on its profiling abilities. AI role in spreading misinformation is a novel research domain (van der Ven et al., 2024); nevertheless, there are expectations that refined social networks further exacerbates social polarization and cultural dissonance (Ecker et al., 2024), including through climate change

content (Galaz et al., 2025; van der Ven et al., 2024). Investigating social-media-AI-misinformation nexus is a promising research agenda to regain public trust in science and deliver climate action.

Misinformation cognitive side-effects are magnified on social media featuring false expectations about social networks tailored biasely by algorithms, with special attention to misinformation continued influence effect, motivated reasoning, dogmatic and other ideological stressors, information-seeking behavior, confirmation bias, and, ultimately, outright rejection of science. Expectations created by social media users make them more susceptible to group derogation while amplifying cognitive dissonance susceptibility (see Figure 18). Furthermore, updating information about social-media-AI-misinformation nexus can help explain why gateway response effect exists and why many misrepresentations of science persist.

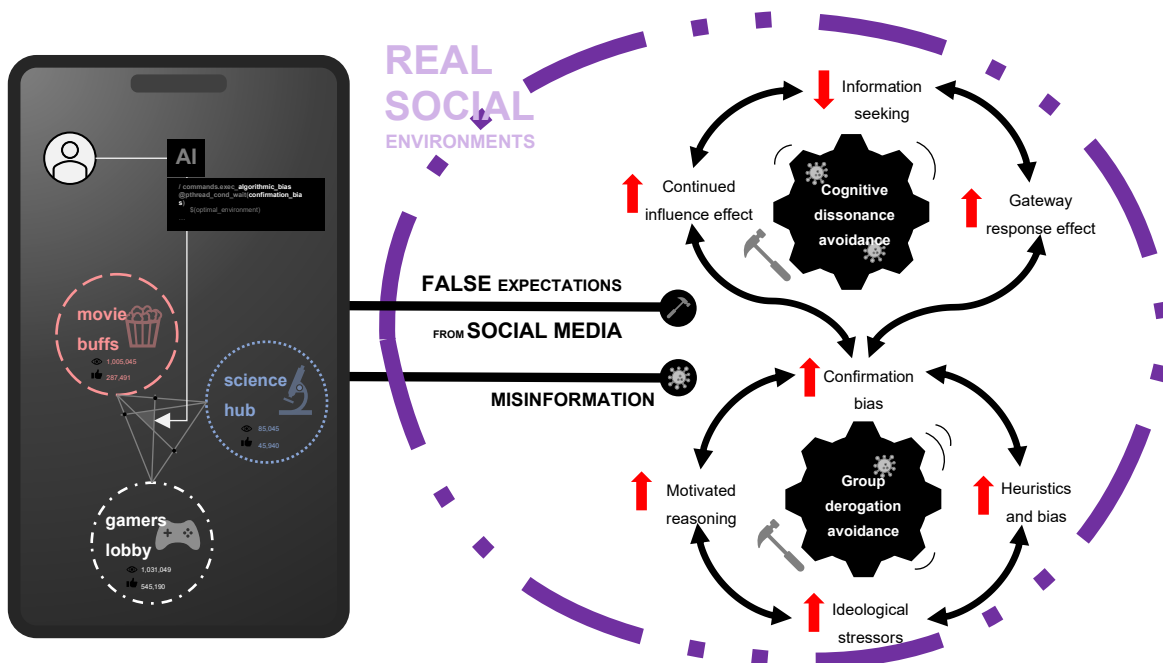


Figure 18. Social-media-AI-misinformation nexus brief picturing social media and AI side effects along with misinformation cognitive effects.

Social media users cope with environments where discussing information through multiple perspectives has more often a polarizing effect over a beneficial exchange of knowledge. Social networks of general audiences are getting farther away from epistemological humility by the day, but they should reconcile. Scientists depend on discussing findings with peers, despite agreement over politics, religion, music taste or any other personal preferences. They put aside their differences otherwise science would not progress. Social media sells idealistic views of social relations that indulge false expectations of *real-world* social environments. Those false expectations, misinformation and individuals' attempts to avoid

group derogation or segregation boost the social-media-AI-misinformation nexus cycle. Ultimately, eroding personal interaction outside those controlled environments. Studying social-media-AI-misinformation nexus can be supplemented by promoting science awareness in general audiences. Shaking their urge for confirmation bias laid on social niches created by algorithms while upgrading their own cognitive and scientific skill toolkit.

Conclusion

One question for the reader before finishing. Was the reader annoyed or tired of reading repeatedly words like “denial” or “denialism”? And simply passing through “climate change” so many times? If you did, I would not be surprised because “denial” appears 233 times throughout the text and climate change 206 times. However, this question does not concern their overall verbal frequency. Did the reader get annoyed right up in the beginning? If so, you may carry a common reaction of deniers who turn off attention whenever confronted with content out of their interest that defies pre-established beliefs (see Schulz et al., 2020 for an elegant analysis of information-seeking behavior). It is more persistent than most admit.

Climate change is a politicized and morally charged topic. Most people with satisfactory climate change awareness, independent from their climate literacy, know that climate change impairs populations worldwide and their consumption impacts the most those facing famine and water scarcity without economic capacity to respond. Being confronted by words like “denial” and “climate change” reminds them of failing to assist those vulnerable populations. Most know that humans are exhausting Earth resources while Earth loses resilience, exposing future generations to uncharted conditions. The path for action denial investigation is spotlighted here, yet climbing the railroad requires momentum from synchronous pushes of educators, science communicators and researchers.

This is a call to safeguard future generations. Climate change and misinformation are indeed global problems. The movie *Don't Look Up* (2021), starring an opulent cast composed of Meryl Streep, Jennifer Lawrence, Leonardo DiCaprio, tells us a fictional story that shows what can happen when decision-makers and citizens don't look up for scientists' warnings.

Humans failed to secure Earth system within Holocene-like conditions, despite scientists' early warnings about climate change. Revolutions have shown that mistakes are not endings. Erring is a *perfect moment* to reevaluate, adapt and learn. Making mistakes is part of learning; whenever researchers are confronted with unexpected results, curiosity enters to make them take a step back, repeat experimentation and reassess data. Inclusively, many scientific discoveries came by chance from exploring unexpected realities.

While paving uncharted territory, outside Holocene-like conditions, science and technology advancements will prove to have paramount importance again. General audiences need to understand that science is not perfect. It is a continuous enterprise and deals with

uncertainties, like any other human fabrication. Still, science is Humanity's most valuable asset for preventing derailing outside sustainable paths.

In desperate periods when present solutions fail, scientists, researchers, engineers and tech-developers work tirelessly to comprehend those challenges and find solutions. While humans regain trust in science and technology, they should reconnect with nature to nurture social values and norms. One question came to mind. When was the last time that the reader sat in a log by a lake or a riverside just watching life's real-time broadcast? Try it. It has the richest cast of any movie. When you notice flowers mesmerizing bees, hear birds and waterflow murmuring while the breeze drifts around your body, nature and life will prove to be beautiful and meaningful merely by existing. Once there, reason about what we were as a species, where we sit now and what future we want for us, our children and other beings. Those meditations unveil why protecting nature and life is necessary.

Humanity is not doomed to fail. Misinformation and climate change can be mitigated. Indeed, climate change and misinformation reveal opportunities to learn, adapt and reassess human-nature interconnectedness and interpersonal relations. The public needs to understand problems to redirect all agendas at once and for all, synchronously. Thus, thesis emerges from epistemological and ethical duties to safeguard those riversides, birds, pollinators and flowers. Ultimately, future will be as bright as the colors we choose to paint today's portrait. Let us choose wisely. Creating momentum with determination to direct life broadcast that we hope others before us had written. Let us choose solidarity. Let us choose courage and compassion. Let us choose Humanity.

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Appendix 1

Survey on climate change beliefs and climate science

This survey, delivered exclusively to legal-age individuals, is conducted with a research purpose, it aims to assess social and behavioral positions towards climate change and climate science. Firstly, we express our gratitude by participating which is voluntary. Furthermore, **it is ensured the data will be treated confidentially guaranteeing the anonymity response for any external personnel of this research team in this research and future publications.**

I consent that the data provided from my survey to be collected for this research and future publications. I understand that I can quit the fill-out anytime without any penalty.

☐ Yes, I do.

SECTION 1 – Sociodemographic questions

The gathered data from this research is anonymous, hence, it is not intended that you answer what should be socially desirable, but what you effectively think, know, and do. Remember that for this research to excel, it is mandatory **to understand reality like it is**, therefore, do not go back to change your previous choices. Only in this way, research can improve society.

1. Select which option corresponds to your **sex**.
 Female.
 Male.
 Other. _____.
2. Indicate your **age in a number response**, e.g., "27".
 ___ years.
3. Select your **nationality**.
 List.
4. Indicate your last obtained academic **qualification**.
 Highschool.
 Technical Course.
 Degree.
 Master degree.
 PhD or higher.
5. Select your **civil status**.

Single.
 Married or United in a partnership.
 Separated.
 Divorced.
 Widow.

6. Indicate how many **children do you have in a number response**, e.g., "0".
 ___ children.

7. Indicate your **current labor or professional stance**.
 Unemployed.
 Student.
 Occasional services.
 Student worker.
 Employee.
 Freelancer.

8. Indicate your current economic situation regarding your **annual net income**.
 Equal or less than € 7,703.
 Between € 7,703 and € 11,623.
 Between € 11,623 and 16,472.
 Between € 16,472 and € 21,321.
 Between € 21, 321 and € 80,000.
 Higher than € 80,000.

9. Choose the **political ideology** that suits better with your ideals.
 Left-wing or liberals.
 Left-centered.
 Center.
 Right-centered.
 Far-right or conservative.

10. Pick the **religious ideology** that suits better with your ideals.
 Atheism.
 Agnosticism.
 Christianity.
 Hinduism.
 Buddhism.
 Islam.
 Other. _____.

SECTION 2 – Are you ready for what is yet to come?

The collected data is ensured to be treated confidentially guaranteeing the anonymity response for any external personnel of this research team in this research and future publications.

1. Answer briefly the following question.

1.1. What are the **behavioral changes in your daily activities** that may contribute further to mitigating climate change? Indicate at least three.

1.2. Are you able to mention at least **three causes and three consequences of climate change**? If so, indicate them.

SECTION 3 – Is the climate truly changing?

2. **Classify the following sentence regarding agreement** [from Strongly disagree (1), Moderately disagree (2), I am not sure (3), Moderately agree (4) to Strongly agree (5)].

2.1. Research that challenges the mainstream point of view is given honest treatment by the scientific community.

2.2. Individual and public investment in climate change mitigation will weaken human prosperity.

2.3. Scientists who challenge the mainstream view of climate change present an honest treatment of the scientific evidence.

2.4. Climate change is not a problem yet, it is merely a possible risk.

2.5. Most of the products, goods, and services which we consume and acquire are already very sustainable, their own campaigns show it clearly.

2.6. Humans are significant to have an appreciable impact on global temperature.

2.7. It's prudent to wait for the results of more research before we reduce our nation's greenhouse gas emissions.

2.8. I trust the things that scientists say about climate change.

2.9. Sooner or later scientific and technological evolution will solve climate change.

2.10. If we continue to increase the world economy, we won't need to worry about climate change.

2.11. Human CO₂ emissions cause climate change.

2.12. The burning of fossil fuels over the last 50 years has caused serious damage to the planet's climate.

2.13. If we make abrupt consumption shifts socioeconomic problems will emerge and we will never tackle climate change.

2.14. Climate scientists are sincere in their research into climate.

2.15. Many scientists believe that the climate is changing.

2.16. We have too many problems to deal with to try to reduce our nation's greenhouse gas emissions.

2.17. Most of the warming over the last 50 years is due to the increase in greenhouse gas concentrations.

2.18. The process by which scientific papers are peer-reviewed and published is reliable.

2.19. The scientific evidence that the climate is changing due to human activities is very solid.

SECTION 4 – We want to know more about your beliefs towards climate change

As stated before, the gathered data will be treated to ensure participants' anonymity, therefore, do not rewind to change your previous choices to answer what could be socially desirable. Choose what you truly think in accordance with your beliefs.

3. **Classify the following sentence regarding agreement** [from Strongly disagree (1), Moderately disagree (2), I am not sure (3), Moderately agree (4) to Strongly agree (5).

- 3.1. Overall, trying to reduce our nation's greenhouse gas emissions will be bad for our nation.
- 3.2. Human health is and will be affected by climate change for other risk factors besides temperature.
- 3.3. Climate change is and will be a problem for other countries.
- 3.4. We should be aggressive in our attempts to reduce our nation's greenhouse gas emissions.
- 3.5. Climate change is and will be a problem for Portugal.
- 3.6. Climate change is and will be a problem for me and my family.
- 3.7. The President and Parliament should make reducing our nation's greenhouse gas emissions a top priority in the next 2 years.
- 3.8. Climate change is and will be a problem for other species of animals and plants and for the environment.
- 3.9. Over the next 50 years, the Earth's climate will change very quickly.
- 3.10. Human health will be affected by the rising temperature.
- 3.11. Over the last 50 years, the Earth's climate has been changing very quickly.
- 3.12. Trying to reduce our nation's greenhouse gas emissions will help us also deal with other important problems.

Appendix 2

Descriptors	
Causes	Consequences
GHGs emission	Global warming
Carbon dioxide emissions	Thawn
Use of energy (direct or indirect)	Sea level rise
Industry	Food insecurity
Housing	Extreme climate events
Food consumption (or food waste habits)	Loss of biodiversity
Travel	Social instability and conflict
Transportation	Water scarcity
Deforestation	Soil loss
Climate change denialism	Migration
Consumerism	Increase in surface mean temperature
Business or corporate activities	Loss of nature contributions to people
Invasive species	Zoonotic diseases
Altering ecosystems	More uncertainty
Material footprint	Wildfires
Resource consumption	Heatwaves
Greenhouse effect	Drought
Social or economic inequalities	Desertification
War and conflict	Ocean temperature rise
Overpopulation	Loss of coral reefs
Resource-dependent economy (e.g, heavy machinery, raw materials, or energy-intensive)	Exacerbating the greenhouse effect
Albedo-related appropriate articulately	Affecting indigenous communities
Free-market	Hindering ecosystems' productivity

Table 1. List of acceptable descriptors for valid entries for climate science essentials on cause (on the left column) and consequences (on the right column).