

The Psychology of Pollution: Analyzing How Heuristics Affect Perception of Air Quality and Policy Design

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Abstract

Air pollution is a severe, global issue responsible for millions of premature deaths yearly and economic costs totaling trillions of dollars. Heuristics—mental shortcuts individuals intuitively employ to aid decision-making—are found to affect public perception of this issue due to the subjectivity and complexity of individual discernment based on visual and olfactory cues. This paper examines the critical role of three key heuristics (the halo effect, confirmation bias, and loss aversion) in shaping public perception, often leading to a significant gap between objective reality and subjective experience. The halo effect can be linked to residents systematically overestimating the cleanliness of air in their own homes due to emotional place attachment shaping global evaluations of their living environments. Confirmation bias explains the persistence of entrenched negative (or positive) perceptions of air pollution in the face of objective environmental improvements (or decline). Loss aversion hinders the adoption of energy-efficient technologies, as upfront costs are weighted more heavily as losses than future energy savings are weighted as gains, and disproportionately undermines policies that do not directly offset upfront investment costs. Through a narrative review of foundational psychological experiments and environmental studies, this analysis demonstrates how these heuristics systematically distort risk assessment and hinder effective public response to pollution. The paper concludes by proposing targeted urban, communication, and incentive policies designed to either reduce the effects of these biases or harness them to improve policy response.

Keywords: air pollution perception, behavioral economics, environmental risk perception, cognitive biases, heuristics, confirmation bias, halo effect, loss aversion

1. Introduction

Air pollution stands as one of the most pervasive and severe environmental threats of the 21st century. Millions of premature deaths annually are attributed to exposure (WHO, 2019), taking a toll on global public health. Economic costs amounting to



trillions of dollars—eroding national GDPs and straining healthcare systems—are stark documentation of pollution-induced economic instability. Yet, societal and individual responses to this threat are not dictated solely by these physical and epidemiological facts. Instead, they are filtered through the complex lens of human perception, a process fraught with cognitive shortcuts (i.e. heuristics) that can systematically distort our understanding of risk.

Generally, economic theory rests on the neoclassical assumption that most actors have stable preferences and make well-informed decisions in self-interest. Behavioral economics deviates from this assumption by incorporating psychology and accounting for real-world inconsistencies in rationality arising from cognitive biases, emotions, and context. Behavioral economics explains that people are often unable to fully analyze situations involving economic and probabilistic judgments (Kahneman and Smith, 2002). Individuals thus tend to rely on heuristics to form judgments, which can be systematically biased.

This paper argues that moving beyond neoclassical economic analysis and engaging with the behavioral economics of risk perception—where heuristics play a decisive, often counterproductive role—can enhance the effectiveness of anti-pollution movements.

The imperative for this behavioral approach stems from the fundamental nature of the threat itself. The data and sources cited in this paper focus on the PM_{2.5} pollutant (i.e. fine particulate matter), which is imperceptible to the human senses. Unable to directly “see” the danger, individuals are forced to construct judgments based on imperfect proxies—visual haze, olfactory cues, or physical discomfort. Socially supplied information, such as media reports and hearsay, can also distort judgments. This complex cognitive task draws on our tendency to rely on intuitive mental shortcuts to simplify tasks. These heuristics are essential for efficient decision-making but introduce predictable biases. In the context of a diffuse and scientifically complex hazard like air pollution, the gap between objective data and subjective perception widens. This makes public comprehension and systemic prioritization of the issue vulnerable to systematic error.

Drawing this connection between environmental perception and heuristic-driven distortion has critical implications for policy design. If public concern, personal protective behavior, and political will are shaped more by heuristic-driven perceptions than by objective measurements, then policies based solely on perfect information or rational economic incentives may fail to motivate action. Behavioral economics provides a framework for decoding this disconnect. By examining how specific biases operate within the domain of environmental risk, we may be able to better anticipate public response, design more effective communication strategies, and craft interventions that align with how people actually process information and make choices.

There exists a growing collection of literature on both air pollution and behavioral economics individually, but a key gap persists at their intersection. Behavioral approaches have been recently applied to environmental risk perception; however, they tend to examine cognitive biases within a narrow empirical scope, rather than developing an integrated account across multiple contexts of how the general bias impacts air quality perception as a whole (He and Zhang, 2018; Yang et al., 2018). The systematic application of heuristics—namely the halo effect, confirmation bias, and loss aversion—to air quality perception and pollution-related policy design therefore remains underdeveloped in existing literature. This paper responds to that gap by examining each of these three heuristics in turn, synthesizing psychological and environmental evidence to demonstrate how each independently distorts public understanding of air quality and undermines conventional policy responses.



This paper first provides background on the physical characteristics of air pollution and its documented health and economic impacts, emphasizing the challenge of perceiving an invisible risk. It then analyzes three key heuristics—the halo effect, confirmation bias, and loss aversion—in the context of air pollution.

In Section 2, we clarify the methodology for study selection and data extraction. In Section 3, we take a closer examination of the facts behind air pollution. In Sections 4, 5, and 6, we explore the halo effect, confirmation bias, and loss aversion, respectively. Section 7 conducts an integrated discussion of all three heuristics, and Section 8 concludes.

2. Methodology

This paper adopts a narrative review framework to synthesize existing empirical and theoretical literature on the role of cognitive heuristics in shaping public perception of air quality. A narrative approach was selected on the grounds that the primary objective of this review is thematic synthesis and theoretical integration across disciplines, namely behavioral economics, environmental science, and public policy, rather than an exhaustive enumeration of all available studies, and is thus interpretive instead of systematic.

Literature was identified through searches of Google Scholar, PubMed, Web of Science, and JSTOR, supplemented by reports from international organizations including the World Health Organization (WHO), the United Nations Environment Programme (UNEP), and the Institute for Health Metrics and Evaluation (IHME), conducted from June 2025 to November 2025. Search terms included combinations of the following: “air pollution”, “halo effect”, “confirmation bias”, “loss aversion”, “air quality perception”, “cognitive bias”, and “environmental policy”. The same search combinations were used across databases. No strict date restriction was imposed, as the review deliberately includes foundational experimental studies and theoretical papers, such as Kahneman and Tversky’s paper on prospect theory (1979) and Wason’s paper on the rule discovery task (1960), providing a core, well-tested psychological base to build upon. More recent empirical studies, prioritized from 2000 onwards, were selected to ground these psychological frameworks in contemporary environmental contexts.

Studies were included based on relevance to at least one of the three heuristics under examination, methodological transparency and publication in peer-reviewed journals or by globally recognized international institutions; purely anecdotal or non-empirical commentary was excluded from citation. Findings were then organized thematically; for each heuristic, foundational experimental evidence establishing the psychological mechanism was identified first, followed by domain-specific studies applying that mechanism to air pollution perception or responsive behavior. Policy implications were derived inductively from the patterns observed across studies within each thematic cluster, with the aim of translating behavioral insights into actionable regulatory recommendations. Simple policy recommendations were then constructed to directly address the identified gaps.

3. Background

As touched upon in the introduction, air pollution represents one of the most significant environmental health risks of the modern era, with profound implications for public health and economic productivity. Simultaneously, perception of this risk is a complex psychological process, and may be filtered through cognitive biases, transforming measured pollution levels into varying interpretations from individual to individual. This section outlines the fundamental nature of air pollution as a



physical phenomenon, its proven impacts, and the nuance involved in human perception, thereby establishing the necessity of investigating the heuristics that shape this perception.

Air pollution is the “contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere” (WHO, 2019, p. 1). Studies cited later in this paper will focus on levels of PM_{2.5} as a measure of air quality due to the seriousness of its health consequences and geographical ubiquity (Henning, 2024). However, other key pollutants include PM₁₀; nitrogen dioxide (NO₂) and sulfur dioxide (SO₂), primarily from combustion processes; and ozone (O₃), a secondary pollutant formed in the atmosphere. Perception of air pollution varies from pollutant to pollutant given their different physical characteristics.

The World Health Organization (WHO) has declared air pollution a public health emergency, with millions of premature deaths annually attributed to exposure (WHO, 2024). As a whole, air pollution accounts for 1 in 8 deaths worldwide at the time of writing (2025), and for 7.9 million deaths in 2023 alone. Regionally, more than 90% of East and Southeast Asia’s population currently breathe air with unsafe levels of PM_{2.5} and ground-level ozone (UNEP, 2024). Additionally, disease outcomes are severe: according to the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2023, particulate matter pollution alone was the second-leading risk factor for early death and poor health globally (IHME, 2023). In particular, studies have shown PM_{2.5} exposure is associated with an increased risk of cardiovascular and respiratory diseases, lung cancer, stroke, pneumonia, depression, and diabetes (Sukuman et al., 2023). Exposure has also been linked to several other conditions, such as asthma, bronchitis, breast cancer, etc., but concrete causal linkage warrants further investigation (Sukuman et al., 2023).

Apart from destructive health effects, air pollution also weighs heavily on countries’ balance sheets. Globally, Estimates project a 2.9 trillion USD global economic cost, equivalent to 3.3% of the world’s GDP. PM_{2.5} was found to be single-handedly responsible for 1.8 billion days of work absence, 4 million new cases of child asthma and 2 million preterm births in 2018 (Myllyvirta, 2020). In the UK, air pollution is linked to the depletion of £27 billion due to healthcare costs, productivity losses, and reduced quality of life, or closer to £50 billion if trickle-down effects like dementia are accounted for (RCP, 2025; CBI Economics, 2020). In India, air pollution cost an estimated \$95 billion (3% of the country’s GDP) in the form of reduced productivity, work absences (3.8 billion working days), and premature deaths (responsible for 18% of deaths in India) in 2019 (Berg, 2021). In Southeast Asia, deaths attributable to air pollution are projected to rise 10% by 2050, with costs amounting to 600 billion USD (UNEP, 2024). This figure captures indirect costs such as lost productivity, economic output, and premature deaths.

While the physical, health, and economic evidence of air pollution is critical, it does not, in itself, dictate public response. The perception of air quality is inherently challenging because individual particles of harmful pollutants, such as PM_{2.5}, are invisible to the naked eye, rendering ambient haze an imperfect proxy. Moreover, pollution-related health consequences often trigger delayed physical symptoms. In the absence of perfect sensory information, individuals cannot directly “see” the threat and must instead construct a judgment of an invisible environmental factor: air quality (Fang et al., 2025).

To navigate a world full of such complex and uncertain judgments, the human brain relies on a powerful set of mental shortcuts known as heuristics or cognitive biases. Kahneman (2011) uses a conceptual framework of two “systems”—System 1 and System 2—in the human brain to explain this. “System 1” is fast, automatic, and effortless, allowing us to make countless decisions without the laborious mental effort of our analytical “System 2”. Heuristics are the rules of thumb System 1 employs—they are typically effective but come with a trade-off: they can systematically lead us away from purely rational



assessment and towards predictable errors.

These cognitive processes are not a sign of intellectual failure, but rather a feature of our mental machinery evolved for efficiency. When faced with the daunting task of assessing an invisible danger like air pollution, it is cognitively more efficient to replace the hard question “What is the current concentration of PM_{2.5}?” with easier ones such as “Does the air look hazy?” or “Does it smell bad?” Common proxies for pollution levels include visual cues (haze or smog), olfactory cues (smell of smoke, exhaust, or industrial emissions), and contextual and somatic cues (media reports, seeing people wearing masks, or experiencing physical symptoms such as coughing or eye irritation). However, these proxies are imperfect and can be misleading—a clear, sunny day may still have dangerously high ozone levels, while a foggy day might be mistaken for severe smog. This reliance on physical cues makes the perception of air quality highly susceptible to the unconscious use of cognitive biases, as it facilitates a shift from a data-rich to cue-driven decision-making process and introduces perceptual vulnerabilities (Boso et al., 2025).

Consequently, the public’s perception of air quality is not a direct reflection of objective data but rather a heuristic-driven judgment, which in turn shapes personal behavior, public concern, and political will. The following three sections look into three specific cognitive biases: the halo effect, confirmation bias, and loss aversion.

4. Halo Effect

If one were to encounter another individual for the first time and were treated warmly and amicably by them, one would likely associate them with several other positive qualities, without any real evidence to support those assumptions. This is due to the human tendency to form an overall judgment of a person or object from a single lasting impression. We can apply this in a general context where observation of a single positive or negative trait impels judgment in every other aspect. Formally, this is known as the ‘halo effect’.

The halo effect was first described by American psychologist Edward Thorndike in his personality studies and has since been one of the most widely known and discussed cognitive biases. Nisbett and Wilson (1977, p. 250) outline the phenomenon as ‘the influence of a global evaluation on evaluations of individual attributes of a person (or object)’. We can understand the heuristic as a mental shortcut that alters judgment when a positive or negative impression of a person, place, or object in one area influences our overall perception and assessment of them, even in unrelated areas.

Its existence has been tested and studied at length. Notable evidence comes from Nisbett and Wilson’s experiment (1977) on college students who watched videotaped interviews of the same instructor. Participants were assigned one of two treatments—one in which the instructor was warm and friendly, and one in which the instructor was cold and distant—and then asked to rate the instructor’s likeability, physical attractiveness, mannerisms, and accent. The halo effect was measured quantitatively by calculating the difference in average ratings for each category between warm and cold treatments.

The warm treatment produced consistently higher ratings across all measures. In particular, warm-treatment participants judged the instructor’s appearance and accent more favorably, quantitatively supporting the existence of a halo effect in play by showing a measurable shift in the evaluation of traits unrelated to the evidence presented. However, this person-perception experiment does not draw a direct link to place-based air-quality judgments.

Fundamentally, the halo effect causes our general impression of an entity to shape our view of its unknown attributes. The



relevance of this heuristic to air quality perception is due to the ambiguity of air quality as an attribute. If one is emotionally attached to the place where they live (quantified by the difference in perceived air quality between home and city), the positive feelings evoked when thinking about their homes would subsequently color perceptions of air quality as clean and favorable (Hofflinger et al., 2019). Since global evaluations can be powerful enough to override other available objective data, the phenomenon likely explains why people in highly polluted cities still perceive their neighborhood air quality positively. As a result, vigorous public awareness campaigns and a wide array of comprehensive research into the adverse health effects of poor air quality have yet to inspire a systemic overhaul of pollutive practices. This is as if people do not perceive the air they inhale as hazardous, they will not make an effort to rectify their habits to protect themselves (D'Antoni et al., 2017).

Previous research has examined the impact of the halo effect on individual perception of air pollution in specific contexts.

One such observational study was conducted in Southern Chile (Boso et al., 2020). As cited, wood-burning stoves are one of the main culprits behind the high rates of pollution in Chile. Despite the availability of a wide range of technological options to replace stoves, the sector still exhibits high levels of pollution. Outdoor and indoor pollution persists despite aggressive government intervention, including measures such as refurbishment subsidies and prohibitions on firewood use, suggesting the involvement of a halo effect. However, alternative explanations such as fuel availability, cost, cultural practices, and enforcement are to be acknowledged as well. The study zeroes in on indoor air, noting that people tend to spend more than 80% of their time indoors.

Residents across 81 homes in Temuco and Padre Las Casas filled in questionnaires on perceived indoor and outdoor air quality, which were then compared to on-site sensors and evaluations made by inspectors. The questionnaire included brief ratings on current air quality, a longer survey on general air quality, and additional questions on pollution severity, health concerns, demographics, and home characteristics.

Air healthiness was defined by the threshold of $25\mu\text{g}/\text{m}^3$ based on recommended WHO levels (Unhealthy if $>25\mu\text{g}/\text{m}^3$ and Healthy if $\leq 25\mu\text{g}/\text{m}^3$). The detected indoor and outdoor PM_{2.5} levels reached peaks of $144\mu\text{g}/\text{m}^3$ and $74\mu\text{g}/\text{m}^3$ respectively, and had daily means of $33.07\mu\text{g}/\text{m}^3$ and $35.37\mu\text{g}/\text{m}^3$ respectively, both falling under Unhealthy by objective measurement. However, on a scale of 1-9, the average rating by residents of home air quality was 6.08—indicating a Healthy perception—while average neighborhood and city air quality ratings were 4.33 and 3.83, respectively. However, inspectors were found to overestimate air quality across the various domains as well. But relative to inspectors, residents' ratings leaned more positively for home air quality ($p=0.001$). Therefore, a 'Home Halo Effect' is measured by quantifying the difference between overestimation of indoor air quality in polluted households between residents and inspectors. Residents overestimate air quality by 80% while inspectors only by 70%, meaning a 10% halo effect according to the authors' definition, whereby the percentages represent the percentage difference between average subjective evaluation and the objective measurement.

Building on the questionnaire data, Hofflinger et al. (2019) sought to further establish the mechanisms that determine public perceptions of air quality as well as prove the prevalence of the halo effect over other related elements. Several independent factors—household income, education level, age, presence of respiratory ailments, number of wood-burning stoves, and whether they live in areas where wood-burning stove usage is restricted—were weighed against data collected on air quality evaluation. Results displayed a clear pattern of better subjective evaluation of air quality at home, as compared to the city or the neighborhood—61% of respondents rated home air quality better than the city, while only 7% thought it was worse. The



mean value of the halo effect variable was positive, confirming a general trend of perceiving home air as cleaner than it is. These results are consistent with a similar spatial cognitive bias, the “neighborhood halo effect” (Bickerstaff and Walker, 2001), termed in accordance with evidence found that individuals generally perceived communities in close proximity to theirs to be less polluted than others (Rankin, 1969). Both studies support the finding that people rate environmental conditions in their immediate surroundings as significantly better than broader or more distant areas.

Since the significance of the halo effect in public perception of air quality has been well established through quantitative studies, applying these insights to urban policy could lead to improvements. After all, the public’s understanding of and response to air pollution can have significant implications for the effectiveness of government interventions aimed at fostering the health and wellbeing of urban residents (Hofflinger et al., 2019). We might even argue that the success of mitigation policies is largely dependent on a thorough understanding of people’s attitudes towards indoor and outdoor air quality.

A proposed application is that governments can provide subsidies or tax rebates to real estate projects that meet a high threshold of integrated air-purifying green infrastructure, targeting this support in neighborhoods that already carry a strong positive reputation. As residents and outside observers already hold a favorable global impression of such neighborhoods, this positive impression should color their evaluation of the air-purifying infrastructure introduced. This means the green design features are more likely to be judged favorably, as more effective, more desirable, or more worth emulating. However, it is important to note potential equity concerns with such a scheme; fashionable neighborhoods are typically more affluent, so subsidy provision may neglect less well-off neighborhoods that lack the additional income to integrate sustainable design.

At the community level, local environmental agencies could partner with platforms to offer verified “Green-Status” badges on their user profiles, earned by documenting air-friendly actions (e.g. using public transport, installing an air-quality monitor). This allows environmental sustainability to be associated with social credibility (Casillia and Hickey, 2016) and cast in its positive halo. Since individuals are inclined towards accumulating social capital (Weiler et al., 2022) and follow social trends, being eco-conscious will come to be seen as fashionable, encouraging widespread adoption of green behaviors through social proof. That said, we should acknowledge the issues of performative behavior and unequal platform access, which could compromise the initiative’s effectiveness in achieving real and widespread behavioral change.

5. Confirmation Bias

While many may consider themselves open to new ideas, individuals tend to cherry-pick and interpret information in a manner that adheres to their existing beliefs, rejecting or discounting contradictory information. This phenomenon is attributed to “confirmation bias”, which Nickerson (1998, p. 175) defines as “the seeking or interpreting of evidence in ways that are partial to existing beliefs, expectations, or a hypothesis in hand”.

Following in the footsteps of philosopher Karl Popper (1959/2002), who believed hypotheses should be falsified instead of confirmed, Wason (1960) sought to experimentally demonstrate the existence of a confirmation bias. Participants were given three numbers “2-4-6”, told that the triple satisfies a predetermined rule, then asked to infer the rule by proposing their own triples and receiving feedback after each attempt. Participants typically formed a hypothesis on the rule (e.g. “consecutive even numbers”) then tested their hypothesis by only proposing triples that satisfied the rule (e.g. “4-6-8”, “6-8-10”, “20-22-24”). As feedback was always positive, their mistaken assumptions were reinforced till they ultimately presented their



incorrect hypotheses. In actuality, the rule was simply “ascending numbers”. Their tendency to seek supporting rather than disconfirming evidence exhibits the use of confirmation bias to arrive at their eventual conclusions (Oswald and Grosjean, 2012).

Expanding on this, Lord, Ross, and Lepper (1979) examine how confirmation biases go further to increase belief polarization—rather than decrease or leave it unaffected—when mixed or inconclusive findings are assimilated by proponents of opposite viewpoints. Their study explores views on capital punishment between two groups of subjects recruited such that they were evenly split between being pro-deterrence and anti-deterrence. The study consists of two stages. In the first stage, subjects were given a brief overview of a study’s results, then asked to rate their change in attitudes toward capital punishment. In the second stage, subjects were provided with a detailed presentation of the procedure, results, and critiques, and again asked to evaluate its impact on their attitudes. This was then repeated with the second study. The following results are presented as percentage point changes. The first stage’s results reported proponents shifting their views 3.75% towards becoming more in favor of capital punishment, whereas opponents shifted 3.13% towards being more opposed. Notably, the divergence widened in the second stage, with the beliefs of proponents and opponents strengthening in opposite directions by 9.38% and 10.6% respectively, despite substantial evidence being provided for both supporting and opposing views. Such data strongly supports the view that mixed data can lead to increased polarization rather than uncertainty and moderation.

Air pollution has been a recognized problem for millennia (Fowler, 2020). Entrenched beliefs about atmospheric pollution, often solidified as social stigmas, can persist even when their original scientific basis becomes outdated (King, 2014; Schwartz, 2004). This persistence helps explain the limited impact of modern information campaigns, which seem to prompt limited environmental action (Ramirez et al., 2019).

Previous research, albeit sparse, is consistent in supporting the correlation between confirmation bias and air pollution. Schwartz (2004) took an observational approach by comparing objective air pollution rates in the United States against subjective evaluation by citizens. He cited public polls which found that the majority of Americans believed air pollution has gotten worse in the past 10 years (66%) and would continue to get worse (67%). On a state level, 78% of Californians were reported to believe the state has hardly made progress in solving environmental problems, and around 80% of New Yorkers rate air pollution as a “very serious” or “somewhat serious” problem, as do 77% of Texans. In fact, actual ozone level data reflect that the US has made dramatic progress in reducing air pollution over the last few decades, and most American cities now enjoy relatively better air quality than in the past. The nation’s monitoring stations registered ozone in excess of federal standards more than 12 times per year in the early 1980s, while the end of 2002 saw a fall to 4 exceedances per year. The considerable improvement in air quality should be perceptible, yet there remains a large disconnect between perception and reality. Based on the evidence presented, it is inferentially likely that the presence of confirmation bias led individuals to cling to historically negative viewpoints of American air quality and overlook objective improvements, impeding their ability to perceive environmental impacts generated by measures put in place to mitigate air pollution. However, the possibility of alternative explanations such as media exposure, uneven local improvement, and distrust of official data is to be acknowledged. Although the above data is historical, the long period over which the study was conducted offers insight into the enduring nature of confirmation bias, which is relevant to current policy design.

An observational study by King (2014) probes cases where confirmation bias contributes to false perceptions of air pollution due to influence from preconceived notions tied to socioeconomic levels. The study is set in Chicago, where—in contrast to the national trend—non-Hispanic African Americans are slightly less likely than other groups to live near toxic-releasing



facilities and Hispanics are more likely to be exposed—consistent with a national tendency for higher environmental risk near concentrations of immigrants. Key results are as follows:

Table 1: Summary of statistics for socioeconomic groups by proportion by air quality rating (adapted from King, 2014, p. 21)

Air quality rating	Poverty rate of raters	Proportion of African American raters	Proportion of Hispanic raters	Additional notes
Poor	21.5%	37.9%	33.6%	46.9% of residents without a high school diploma rated air poorly; 28.4% of college graduates did so.
Excellent	10.9%	22.5%	20.9%	-

Despite the stark perceptual difference, the general difference in objective pollution levels between people who reported “Excellent” air and “Poor” air is actually small. Thus, social cues (in this case, racial demographics) emerge as a likely key predictor of air quality, a finding consistent with a neighborhood stigma interpretation. However, given these are correlations from observational data, there can be several potential drivers of these associations, including news coverage patterns or literacy levels.

King suggests a “neighborhood stigma” theory wherein “once a place acquires a negative reputation, respondents will tend to rely heavily on that evaluation when inferring neighborhood characteristics, particularly in the absence of domain-specific information or experience”. While place reputation appears to be affected by individual bias of racial and ethnic composition in Chicago, other considerations may be more salient in other areas. This relates back to confirmation bias by demonstrating how people are inclined to make judgments about air quality that align with preconceived social beliefs.

Fully grasping the implications and applications of confirmation bias can enable policymakers to not only alleviate its negative effects but harness it to positively influence public behavior. Two communication strategies are suggested for regulators to adopt to aid in mitigating confirmation bias barriers in the battle against air pollution.

The first strategy uses confirmation bias to link environmental messaging to identity and values, drawing on research into political moral framing in environmental action by Hurst and Stern (2020) and Boso et al. (2025). To do this, policymakers can frame pollution issues in a manner that aligns with different groups’ values. This plays on their confirmation biases, the presence of which is consistent with evidence from Ditto et al.’s (2017) meta-analysis showing that political partisans reject information that counters their pre-existing beliefs. This can be particularly useful for garnering conservative support for environmental policy, given their relative distrust of climate science (Washburn and Skitka, 2017) and general refutation of anthropogenic climate change (Ballew et al., 2019). For instance, conservatism as an ideology favors a free market economy. Thus, an economy-oriented narrative that emphasizes economic benefits from efficiency gains or economic costs of environmental disasters and resource depletion can be more persuasive than traditional information sharing that describes the effects of climate change.



The second one involves curating source networks and information channels that hold sway over different groups. This approach leverages confirmation bias by strategically delivering the value-aligned messages from the first strategy through sources and channels the target audience already trusts and seeks out, drawing on Shen et al.'s (2023) evidence for the influence of trusted community-based organizations in public health messaging. For a conservative audience, this means partnering with and amplifying messages through faith leaders, military veterans' groups, and center-right media personalities. For a progressive audience, effective channels include social justice organizations, educational institutions, and progressive media outlets. The above suggestions rely on a simplification of political groups and acknowledge variation within groups.

However, the ethics of using confirmation bias should be considered before any real-world integration, for there is a thin line between value-aligned communication and manipulative targeting. To ensure ethical integrity, all information conveyed should remain factually correct and scientifically consistent, with only the emphasis in messaging varying. This is to further prevent unintentionally deepening divisions by allowing different groups to receive substantially different narratives (content-wise) about the same issue.

6. Loss Aversion

Kahneman illustrates a standard coin-toss gamble experiment in *Thinking Fast and Slow* (2011). He asks participants how much they would need to gain if they stood to lose \$10 on tails. The typical response was approximately \$20, suggesting a tendency to place more value on losing money as opposed to gaining money. This is a textbook example of the loss aversion hypothesis.

The loss aversion hypothesis was first introduced by Kahneman and Tversky (1979) as an essential feature of prospect theory, which suggests people make decisions based on perceived value relative to a reference point instead of a static utility. The hypothesis is that "the response to losses is more extreme than the response to gains. The displeasure associated with losing a sum of money is generally greater than the pleasure associated with winning the same amount" (Tversky and Kahneman, 1981, p. 454). A consequence of loss aversion is that it can lead to inconsistencies in risk preferences, i.e. the degree to which an individual prefers a sure amount to a gamble for any arbitrary risk. It is important to note the distinction between loss and risk aversion, where the latter refers specifically to a preference for the certain outcome over a gamble with the same expected value (Menezes and Hanson, 1970). Loss aversion can therefore elicit individuals' risk-averse behavior, and such behavior may be used to infer loss aversion.

Karle et al. (2015) demonstrated the mechanisms of the heuristic in an experimental setting using choices among different lotteries. They gave subjects two series of choices, with 6 choices each, where they had to choose between lotteries and sure payments. For Series A, subjects had to make 6 choices between a lottery with a 50% chance of winning 1 Euro and a 50% chance of winning nothing, and a sure payment of S. S was either 10, 20, 30, 40, 50, or 60 Eurocents. This choice purely elicits their risk preferences without involving loss aversion as it only comprises gains. A risk-neutral individual would be indifferent between the lottery (which has an expected value of 50 Eurocents) and a sure payment of 50 Eurocents. Subjects who choose sure payments below 50 Eurocents over the lottery are risk-averse, while those who choose the lottery over sure payments above 50 Eurocents are risk-seekers. In the experiment, only 23.3% of participants picked the lottery over sure payments above the lottery's expected value (risk-seekers), showing that most participants were either risk-neutral or risk-averse.



In series B, subjects had to make seven choices between a lottery that gave a $\frac{1}{3}$ chance of winning €1 and a $\frac{2}{3}$ chance of losing R Eurocents, and a sure payment of zero. R was either 0, 10, 20, 30, 50, 70, or 100 Eurocents. This choice is where loss aversion comes into play. Going by the same logic in Series A, a risk-neutral individual would be indifferent between a lottery of expected value zero (when $R=33$) and the sure payment. Meanwhile, an individual that exhibits loss aversion, and thus risk-aversion, would be willing to accept a payment of zero more often for any given R. In the results of the experiment, 16.8% of participants made a choice that is more risk-averse compared to what they did in Series A and therefore displayed a change in behavior due to loss aversion.

Pollution links closely to loss aversion in terms of environmental action by individuals or groups. Whether or not to undertake a pro-environment action is a choice individuals have to make. That decision-making process likely involves weighing private benefit derived against private cost personally incurred. Kollmuss and Agyeman write that “if the person decides between two possible items, one energy-efficient and the other not, he or she will only choose the energy-efficient item if the payback time for the energy saved is very short” (2002, p. 249). This is consistent with loss-averse behavior as it suggests a greater valuation of loss of time than possible environmental benefit. Moreover, since partaking in pro-environmental behavior often requires a lifestyle change and a loss of the familiarity and safety in one’s usual routine or incurs implementation costs, loss-averse individuals are likely to opt for the non-environmental option. A limitation of this analysis is that it does not disentangle loss aversion from other alternative explanations such as heterogeneity in time preferences and liquidity constraints.

Bartczak et al. (2015) explores loss aversion in the environmental domain via a within-subject field study examining choices over a risky environmental good, wildfires in Poland. The study adapts Tanaka et al.’s (2010) experimental lottery design where participants chose among lottery pairs framed in terms of environmental outcomes of programs to reduce the risk of forest wildfires rather than monetary payoffs. In the first two treatments, which involved only gains (choice between programs with varying success rates), $\approx 75\%$ of respondents were risk-averse. In the third treatment, which introduced the possibility of losses through greater forest destruction (choice between programs with varying success and failure rates), $\approx 85\%$ of respondents were risk-seeking. This suggests that the introduction of losses substantially altered choice behavior. The paper thus provides evidence for loss aversion in the environmental context.

More recently, Knobloch et al.’s (2019) paper displays loss aversion’s widespread applicability to the global energy model, using residential heating technology uptake as a case study. The sector was chosen because decisions are overwhelmingly made by consumers, but not predominantly influenced by other interfering cultural factors (Michelsen and Madlener, 2013). Additionally, the sector accounts for the largest share of direct greenhouse gas emissions by households. It is a simulation study that performs analyses at both a global level and the level of individual countries, simulating future heating technology diffusion across 59 world regions.

The study employs a model that simulates consumer decision-making and weighs benefits (convenience, environmental benefits, etc.) and costs (upfront costs, operating costs, etc.). The model is run twice, with default loss aversion parameters and without. The model is used to compare the efficacy of four decarbonization policy scenarios with and without the effect of consumer loss aversion. The aim is to assess how loss aversion influences model projections of technological change and policy effectiveness, especially as current energy models often assume optimal consumer decisions, which might lead to overly optimistic expectations of climate policy efficacy. Results indicate that loss-averse decision-makers are less likely to adopt energy-efficient technologies, as higher upfront costs are often perceived as losses with a stronger impact than future



energy savings (evaluated as gains). This asymmetric valuation results in a "conservative shift" where preferences for current technologies are strengthened, reducing uptake of newer technologies.

The model further shows that subsidies were relatively more effective in reducing emission levels than carbon taxes as they directly address the pain point for loss-averse consumers—high investment costs for renewables—while taxes do not. On the other hand, projections show that a carbon tax of 200 €/tCO₂ while considering loss aversion and a carbon tax of 100 €/tCO₂ without considering loss aversion achieve a similar reduction in overall emission levels. Thus, taxes require more drastic implementation, which is likely to be received poorly by the public. In short, the model indicates that a tax rate about double that of ideal projections (without loss aversion) is required to attain similar outcomes.

These differences in outcomes suggest that consumer behavior, specifically loss aversion, has a profound quantitative impact on the feasibility and required intensity of climate policies.

Taken together, these findings suggest that loss aversion may play an important role in environmental pollution and inaction. Thus, policymakers may be able to use this heuristic to increase the effectiveness of pro-environmental policy. While loss aversion is often discussed in the context of how it can hinder the effectiveness of policies, there are now several policies and interventions that have sought to actively "make use of" this behavioral trait to achieve desired outcomes. Current and previous approaches often involve framing choices to emphasize potential losses, thereby leveraging individuals' stronger aversion to losing something compared to gaining an equivalent amount.

A notable application is in the design of incentives for healthy behaviors, where individuals are offered "insurance" (a sum of money) but told they will lose it if they do not achieve a certain healthy behavior (e.g. attending an appointment or making a healthy choice). The prospect of losing this already "allocated" amount can be motivating and has been shown to encourage high rates of health behavior uptake (Meeker et al., 2015).

This strategy can be adapted for pollution reduction in various ways, particularly because the considerations underpinning pro-health and pro-environmental behavior are similar. Both rely on long-term commitment for delayed gains, and overlap in terms of sustainable lifestyle habits. A "green bonus" can be granted to households at the start of each month (e.g. credit on their utility bill) but lose part or all of it at the end of the month if they exceed the given emission threshold. This creates a stronger motivation to adopt greener appliances and habits than a standard rebate system by exploiting loss aversion, as households are more sensitive to losing a granted credit than to forgoing an equivalent unheld gain. However, this design raises concerns about one uniform threshold. Large households may be disadvantaged as their consumption is structurally higher; lower-income households often have little room to cut, while higher-income households have more slack and thus an easier path to the bonus, risking a regressive outcome; and renters have limited control over efficiency, insulation, and heating decisions. Thus, adjusted thresholds to accommodate varying baselines are necessary to reward improvement rather than penalize pre-existing consumption needs.

Alternatively, commuters could begin each week or month with a "streak bonus" (e.g. 10% discount on fares) that diminishes if they fall short of their weekly quota. In other words, missing a day of commuting via public transport would constitute a penalty (e.g. - 0.5% off the discount). However, a fixed quota assumes consistent transit access, which does not hold for commuters with disabilities limiting service use, or those in rural or low-density areas where frequency and coverage are constrained by infrastructure, punishing accessibility limits. The scheme also risks disproportionately affecting low-income



commuters who lose their discount due to illness, caregiving, irregular work hours, penalizing them more harshly (since discount makes up a larger proportion of their transport budget) instead of rightfully supporting them.

These examples may help in nudging individuals to adopt greener lifestyle habits more readily.

7. Discussion

Until this point, each heuristic has been examined independently. However, in practice they do not operate in isolation. Although not limited to these three biases, we see evidence of a possible compounding effect within the three heuristics examined in this paper, demonstrating a mutually reinforcing relationship not yet explored in previously cited studies. This section proposes a potential account of how such an interaction might unfold.

One way of conceptualizing this interaction is as a sequential cycle, in which each heuristic builds on the perceptual conditions created by the preceding one. This is not offered as a definitive model but as a plausible account that broadly draws on evidence reviewed in earlier sections.

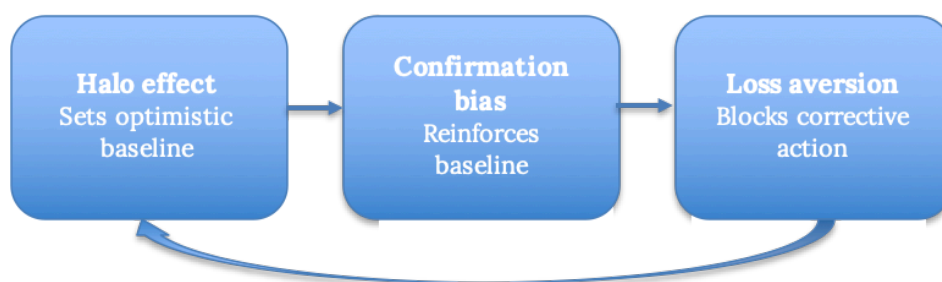


Figure 1: *Proposed framework.*

The halo effect may be understood as the stimulus that establishes the individual's baseline perception of local air quality. The theoretical basis for placing it first in the sequence is that, by definition, the halo effect is a phenomenon of global evaluation—it operates at the level of overall impression, shaping how an individual feels about a place or environment before any deliberate assessment of its specific attributes has taken place (Nisbett and Wilson, 1977). However, alternative sequencing remains possible as prior beliefs or loss concerns can precede place attachment. As demonstrated by Hofflinger et al. (2019) and Boso et al. (2020), (positive) emotional attachment to one's home and neighborhood generates a global positive evaluation that colors assessment of individual attributes, including air quality, in a more favorable direction than objective data warrants. This initial perceptual anchor is not consciously constructed; it emerges automatically from the same System 1 processing that underlies heuristic reasoning more broadly. The critical point is that once established, this baseline does not simply sit passively in the individual's mind; it actively colors how subsequent information is processed.

This is where the confirmation bias plausibly enters, operating as a filter through which subsequent information is screened rather than processed neutrally. Having formed an overly optimistic baseline perception, the individual is now predisposed to filter incoming information in a manner that preserves rather than tests it. A hypothetical example is that on a clear, sunny day, the absence of visible haze may be registered as evidence of clean air; a health advisory may be discounted as overstated;

a neighbor's complaint about air quality may be attributed to hypersensitivity. As Schwartz (2004) and King (2014) demonstrate, this filtering process is capable of sustaining misperceptions across years and even decades, insulating individuals from the corrective influence of objective environmental measures. In this case, the halo-derived baseline provides the very belief that the confirmation bias then works to protect and entrench.

The third stage introduces loss aversion as a barrier to behavioral correction. Even in cases where the first two stages are partially overcome—where an individual does come to accept that local air quality is worse than they had assumed—the translation of updated perception into action faces a further obstacle. As Knobloch et al. (2019) and Bartczak et al. (2015) elucidate, the upfront costs, lifestyle disruptions, and sacrifices of familiarity associated with pro-environmental behavior are experienced as losses, weighted disproportionately against the future gains of cleaner air. Loss aversion, understood as such, functions as the final barrier in the cycle. It is the mechanism by which even a changed perception fails to produce a changed behavior. The individual may acknowledge the problem and yet remain inert.

Taken together, this proposed sequence suggests a possible dynamic in which the halo effect generates the misconception, confirmation bias reinforces it, and loss aversion prevents actionable progress even when negative perceptions are dislodged. Future work could test this hypothesized causal chain using a 2x2x2 factorial experimental design in which the presence or absence of each of the three heuristics—halo effect, confirmation bias, and loss aversion—is independently manipulated as a treatment dimension. While the precise causal ordering and directionality (may be multidirectional rather than strictly unidirectional) proposed above remains an open empirical question, the critical takeaway is that when multiple heuristics operate simultaneously in the same cognitive environment, their combined effect need not simply be the sum of their individual effects: the heuristics may instead act as complements or substitutes, producing an interaction effect that is either larger or smaller than what independent operation would predict.

Two of the cases discussed in earlier sections are worth revisiting through this integrative lens, as they are suggestive of the kind of compounding dynamic described above.

The first is the wood-burning stove context in Southern Chile examined by Boso et al. (2020). Residents in Temuco and Padre Las Casas systematically overestimated indoor air quality relative to both sensor measurements and inspector evaluations—a pattern consistent with the home halo effect. Yet this misperception persisted despite aggressive government intervention, including refurbishment subsidies and prohibitions on firewood use, suggesting that objective information and material incentives that should rationally tip the scale in favor of actionable change were insufficient to shift behavior. This resistance is arguably consistent with confirmation bias entrenching the favorable baseline perception against contradictory policy messaging, while loss aversion simultaneously raised the psychological cost of abandoning familiar heating practices. An important caveat is that their data is purely correlational, so alternative structural explanations are plausible.

The second case is King's (2014) study of air quality perception in Chicago. This illustrates that the compounding dynamic need not operate exclusively in the direction of over-optimism. Here, neighborhood stigma (negative halo effect) generated a pessimistic baseline perception of air quality in predominantly Black and Hispanic neighborhoods, despite the objective difference in pollution levels between high- and low-rated areas being small. Confirmation bias then plausibly entrenched this stigma, causing residents to interpret ambiguous environmental cues through a lens of pre-existing negative expectations. An open research question is whether loss aversion may further have discouraged investment in local environmental improvement, with residents perceiving the costs of action as disproportionate given the low perceived



likelihood of meaningful change. The cycle, in this case, runs in the opposite direction—producing systematic underestimation of air quality rather than overestimation—but the underlying compounding logic is arguably the same.

These two cases do not constitute proof of the proposed interaction. They are better understood as illustrations of contexts in which such an interaction is a plausible contributing explanation for outcomes that individual heuristics alone do not fully account for.

If the compounding dynamic proposed here has merit, it carries meaningful implications for the design of pollution-related policy. Interventions targeting only one heuristic at a time may find their effectiveness partially undermined by the others operating in the background. For example, a communication campaign that successfully challenges a community's confirmation bias, for instance, may still fail to produce behavioral change if loss aversion remains unaddressed—the individual may update their beliefs without updating their behavior, consistent with the intention-behavior gap in medical literature (Faries, 2016).

This suggests that layered policy approaches—ones that address the emotional baseline, the information environment, and the incentives structure in coordinated fashion—may be more effective than single-lever interventions, even if they are considerably more complex to design and evaluate. The individual policy proposals outlined in Sections 4, 5, and 6 might therefore be understood not merely as standalone recommendations but as potentially complementary components of a broader behavioral strategy: reshaping the halo first to establish a more accurate perceptual baseline, delivering value-aligned messaging to work with rather than against confirmation bias, then structuring policy design to align with loss incentives.

However, this interaction remains empirically underexplored, and its precise mechanisms and causal orderings are open questions that future research would do well to address, ideally through experimental and field-based studies designed specifically to examine how multiple heuristics operate simultaneously within environmental decision-making contexts.

Future empirical work may find value in testing the validity of the proposed compounding effect. As an initial, more tractable step toward the full three-heuristic design mentioned above, a factorial design manipulating two of the three cognitive biases (e.g. positive halo effect from place attachment and loss-framing of a proposed remediation) should reveal an interaction effect that affects belief updating when exposed to objectively poor air quality. For instance, participants high in attachment and exposed to loss-framed information should update their beliefs less than the added effects of either factor alone after being exposed to objective evidence of poor air quality. An alternative hypothesis is that the two effects complement each other so their interaction leads to an overall effect that is larger than the sum of the impact of each heuristic in isolation. This two-factor test would serve as a foundation before extending to the full 2x2x2 design needed to capture the three-way interaction among all three heuristics; together, the two designs would allow us to investigate whether the heuristics are complements or substitutes, and improve our understanding of how they operate.

However, a factorial design of this kind can only establish whether the heuristics interact statistically; it cannot on its own distinguish an interaction from a sequential pathway in which one heuristic's effect operates through another. A complementary design could manipulate the halo effect directly, measure an intermediate process such as confirmation-bias-related belief updating, and then test whether this intermediate step moderates the subsequent effect of loss aversion on behavior. This allows the sequential account to be evaluated against the interaction account.



8. Conclusion

The evidence reviewed in this paper has suggested a meaningful influence of heuristics—namely the halo effect, confirmation bias, and loss aversion—in shaping individual and collective perceptions of air quality, often creating a significant gap between objective reality and subjective interpretation. The findings explored in this paper are not merely curiosities of psychology but demonstrations of powerful, systematic forces that undermine the effectiveness of conventional pollution mitigation policies which assume rational, information-driven public behavior.

The halo effect may help to explain how positive emotional attachments to one's living environment as a whole color objective assessment of individual traits like air quality, potentially contributing to overestimations of air quality that could create a false sense of security and insulate people from the urgency of environmental risks. Confirmation bias offers a plausible mechanism by which communities interpret ambiguous environmental cues through the lens of pre-existing beliefs and social stigmas, causing real improvements in air quality to generate less policy-support response than the scale of improvement would warrant, and may even lead to ill-targeted policy actions. However, as the underlying studies are observational rather than experimental, confirmation bias cannot be isolated as the cause of these persistent perceptions, and the association should be read as suggestive rather than demonstrated. Loss aversion reveals a fundamental asymmetry in decision-making: the perceived pain of sacrificing convenience, money, or routine to adopt green behaviors far outweighs the perceived gain of future environmental benefits, creating a powerful inertia against pro-environmental action.

Section 7 tentatively proposes that these heuristics may do more than operate in parallel. If the compounding dynamic there has merit, the picture that emerges is one in which the halo effect establishes a distorted perceptual baseline, confirmation bias entrenches it and protects the baseline from corrective information, and loss aversion prevents updated perception from translating into behavioral change. The result may be a cycle of misperception that is qualitatively more resistant to intervention than any individual bias would suggest.

Crucially, these heuristics not only present obstacles but also offer novel pathways for policy innovation. Countervailing policies may be more effective when they work with, not against, these ingrained psychological patterns. This can be achieved through the following three-step approach. First, we can leverage the halo effect by associating clean air technologies with socially desirable status and community identity. Second, we can harness confirmation bias by framing environmental messages to align with deeply held values of different demographic groups, making sustainable choices feel like affirmations of identity instead of contradicting beliefs. Third, we can draw on loss aversion by restructuring incentives around the avoidance of loss, such as bonds forfeited for non-compliance with green policies—although such loss-framed designs raise ethical and equity concerns as they may disproportionately burden lower-income households for whom the forfeited amount represents a greater relative cost, and may erode public trust if perceived as punitive rather than supportive. The interaction framework further suggests that these interventions may be most effective not as standalone measures but as coordinated components of a layered behavioral strategy.

Bridging the gap between air quality data and public perception requires a behavioral turn in environmental policy. We must go beyond mere information dissemination to strategically reshape the cognitive and emotional landscape in which decisions are made. This review contributes a synthesis of the halo effect, confirmation bias, and loss aversion into a single framework for understanding how heuristics lead to a self-reinforcing cycle of air quality perception, and identifies possible redirections of the same heuristics towards policy design. What remains needed is direct empirical testing of whether related



interventions translate into measurable effects, and whether they do so without disproportionately burdening populations least able to absorb their costs.

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Author Biography

Amber is a student at Raffles Institution with an avid interest in behavioural economics, social policy and environmental studies. Integrating these interests, she pursued an independent review into the linkage between inherent human biases and environmental perception, hoping to offer insight into how behavioural studies can be utilised for sustainable solutions.

Mentor Contribution Statement



Dr. Edoardo Gallo served as the mentor for this manuscript. Dr Gallo's contribution began at the project's earliest stage, when he provided guidance on initiating the research process and helped the author establish an appropriate structure for approaching the topic, including how to organise the review's scope around the three heuristics examined. This early structural guidance shaped the overall architecture of the paper, including the division of the manuscript into background, thematic analysis, integrated discussion, and conclusion.

Throughout the writing process, Dr Gallo provided editorial assistance, reviewing successive drafts of the manuscript and offering feedback on clarity, argumentation, and the coherence of the narrative review as a whole. This editorial input was iterative, with Dr Gallo engaging with the paper throughout the stages of its development rather than at a single point of review.

In addition to structural and editorial guidance, Dr Gallo contributed conceptual input on the manuscript's content. This involved challenging the author's assumptions where claims required stronger justification or more careful qualification, and providing clarifications on conceptual points, particularly whether behavioural economics concepts were applied to the environmental and policy contexts discussed in the paper. This critical engagement helped refine the analytical claims made throughout the review and ensured that inferences drawn from the cited literature were appropriately scoped and caveated.

