



GOODAIR NON-ELECTRIC CAR AIR PURIFIER IN THE MANAGEMENT OF MOTION SICKNESS: A REVIEW OF CLINICAL EVIDENCE AND MECHANISTIC INSIGHTS

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Abstract

Motion sickness during daily car travel remains a prevalent yet underaddressed challenge, particularly within modern and emerging autonomous mobility systems where passengers increasingly assume passive travel roles. Sensory conflict, individual susceptibility, and in-cabin environmental stressors interact to influence symptom onset and severity. Conventional pharmacological and behavioural management approaches present limitations related to side effects, user dependence, and lack of preventive continuity, prompting growing interest in alternative strategies. This review synthesises current evidence on motion sickness in car travel with a focused emphasis on environmental determinants and examines the mechanistic rationale, safety considerations, and practical relevance of the GOODAIR non-electric car air purifier as a brand-specific environmental intervention. A narrative review approach was employed, integrating findings from motion sickness research, environmental health studies, and vehicle-centred comfort literature. Particular attention is given to sensory conflict mechanisms, in-vehicle air quality, and impregnated carbon-based gas adsorption as contributors to passenger comfort. The reviewed literature supports the concept that stabilisation of cabin air quality may reduce exposure to sensory irritants that exacerbate motion-related discomfort. Non-electric in-car air purification emerges as a non-invasive, preventive adjunct aligned with passenger-centric design principles in future mobility ecosystems. Further research across diverse travel contexts is warranted to strengthen the evidence base and clarify long-term implications.

Keywords: Motion sickness; In-cabin air quality; non-electric air purifier; Impregnated Carbon; GOODAIR

1. Introduction

Motion sickness is a complicated neurophysiological disorder that occurs as a result of a disconnection in the sense of the vestibular, visual, and proprioceptive systems. This condition is common among the passengers in normal car travel, where the symptoms are mild discomfort, as in the case of routine car travel, and in some instances, nausea, dizziness and vomiting. Motion sickness is defined by diagnostic consensus as reproducible clusters of symptoms correlated with sensory conflict and not underlying pathology, and supports the relevance of motion sickness as a functional disorder but not a disease entity (Cha et al., 2021). Repeated exposure to lateral and vertical accelerations with low frequencies as a result of daily car movement causes sustained sensory incongruence, predisposing those vulnerable to the occurrence of symptoms. The experimental data that confirmed sensory conflict theory also confirms that the severity of motion sickness can be

greatly manipulated by the adjustment of the vestibular stimulations, which proves the mechanistic centrality of sensory mismatch in vehicles (Allred et al., 2025). The weight of the car-induced motion sickness has only piled up as the mobility patterns have changed. Expanding urban commuting durations, the extensive use of personal automobiles, and the development of autonomous driving technologies have transformed occupants into passive clients instead of active drivers, increasing susceptibility to motion-induced discomfort. The human-based mobility studies point to the fact that comfort-based impairments, such as motion sickness, impair inclusivity and accessibility in advanced transportation systems, specifically among persons with increased sensory sensitivity or disability restrictions (Bastola et al., 2025). Neurophysiological findings show the objective changes in cortical activity during the occurrence of motion sickness after the eyes view visual content, and that repeated exposure has a cumulative effect on neural processing and perceived well-being (Andrievskaia et al., 2023). In addition to personal inconvenience, motion sickness causes low travel tolerance, lower productivity, and poor quality of life, which makes it a population health issue in the modern transportation ecosystem.

The present methods of motion sickness management use pharmacological agents and behavioural countermeasures as the primary options. Antihistamines and anticholinergic drugs continue to be widely used, but the impact on the brain and the side effects of sedation complicate the use of such substances as regular medications in the everyday routine of travelling. Behavioural strategies, such as the use of posture change and fixation with visual strategies, are inconsistently effective and demand long-term adherence of users to them. The prediction tools of the susceptibility point to the presence of interpersonal variability, which means that standard interventions do not adequately cover individual risk profiles (Golding et al., 2021). Similar findings in the field of artificial reality study indicate that the transfer of strategies to reduce motion sickness across settings is not usually successful, highlighting the dependence on the context and the impossibility of controlling symptoms (Chang et al., 2020). The combination of all these limitations indicates the necessity of alternative and non-invasive methods, which would operate continuously without the assistance of human input or exposure to pharmacological agents.

There is an increased focus on environmental modifiers of passenger comfort, especially in-cabin air quality and sensorial load. According to the perceptual studies, the occupants have always related poor cabin air quality with feeling uncomfortable, fatigued, and nauseated, which is behavioural evidence of a significant relationship between environmental stressors and subjective well-being during car travel (Constantin et al., 2016). The observation of volatile organic compounds, traffic-induced gases, and PM in passenger vehicle cabins, even in conventional ventilation conditions, is confirmed by empirical measurements (Faber and Brodzik, 2017). The long-term exposure to these types of contaminants is related to sensory irritation and autonomic responses to stress, which are factors that are involved in the increased cases of motion sickness during longer trips (El Falou et al., 2003). The development of ambient air purification methods, especially the use of adsorption-based operating systems, promises a good approach to reducing the in-cabin environmental stressors. The purification systems developed based on nanotechnology exhibit high effectiveness in the fight against gaseous contaminants that do not require active energies to work, justifying the applicability to closed vehicular spaces (Cao et al., 2021). Passive air purification can operate 24 hours, unlike behavioural or pharmacological methods, minimising sensory irritants that can increase vestibular pain. The concept of incorporating environmental control techniques into vehicle cabins should be understood in the context of the overall tendency toward the human-centred mobility design, where the air quality control should be seen as a topical factor supporting the reduction of motion sickness instead of an independent treatment.

Altogether, the causes of motion sickness in everyday car commuting are the multi-factorial interplay of sensory conflict, personal disposition, and environmental stress factors. The drawbacks of the traditional interventions require the examination of non-invasive and context-sensitive methods. The ideal substitute to the existing mobility systems is environmental and in-cabin interventions, especially those aiming at stabilisation of air quality in modern mobility systems. This changing

opinion forms a basis on which the non-electric car air-cleaning technologies can be considered as sources of motion sickness management in the travelling context. The aims of this review paper are two-fold, to critically synthesize available scientific and clinical evidence regarding motion sickness in everyday car travel with special focus on sensory conflict mechanisms, in cab environment effects, and non-pharmacological management interventions; and also to comprehensively assess the mechanistic reason of the clinical effectiveness, as well as the safety profile, of the GOODAIR non-electric car air purifier according to the clinical study conducted, which will place the brand relevant intervention within the greater context of environmental interventions on the reduction of motion sickness, in total compliance.

2. Pathophysiology of Motion Sickness

2.1 Sensory Conflict and Neural Mismatch Theories

Sensory conflict and a mismatch of the neural stimulation of the vestibular, visual, and proprioceptive signals are the causes of motion sickness. Low-frequency lateral and vertical acceleration during car travel causes discrepancies between anticipated and real sensory inputs related to the generation of sensations of nausea, vertigo, and discomfort (Islam, 2024). The mechanism is enhanced in passive passengers, especially when exposed to predictable but repetitive movements. The sensory conflict theory has continuously appeared as the most popular explanatory theory of motion sickness between real and simulated driving settings in reviews about car and autonomous vehicle travel (Iskander et al., 2019).

2.2 Vestibular–Visual Interaction and Autonomic Responses

Vestibular and visual, thus in interaction, are instrumental in eliciting autonomic responses like nausea, sweating and cardiovascular instability during exposure to motion. The research on human-computer interaction has revealed that people using vulnerable roads are even more sensitive to multisensory discordance that in turn increases autonomic stress reactions to dynamic situations. Further ergonomic research on vehicle cabin design indicates that spatial orientation with human-centeredness and predictability of human interfaces determines the relationship between the severity of discomfort during exposure to long-term motion (Hollander et al., 2021; Jeddi, 2024).

2.3 Individual Susceptibility Factors

The perception of motion sickness differs greatly in the individual because of differences in sensory and cognitive expectation and environmental tolerance. The population-level analyses have shown that exposure history, health condition, and contextual stressors interact to determine the degree of symptoms (Figure 1). Urban mobility research proposes that urban environmental conditions, such as air quality and perceived comfort, have an indirect effect on susceptibility by placing physiological stress on the travel experience. These results highlight that motion sickness susceptibility is a sign of innate sensory sensitivity and external forces in the environment that an individual must experience when travelling regularly (Hesketh et al., 2017).

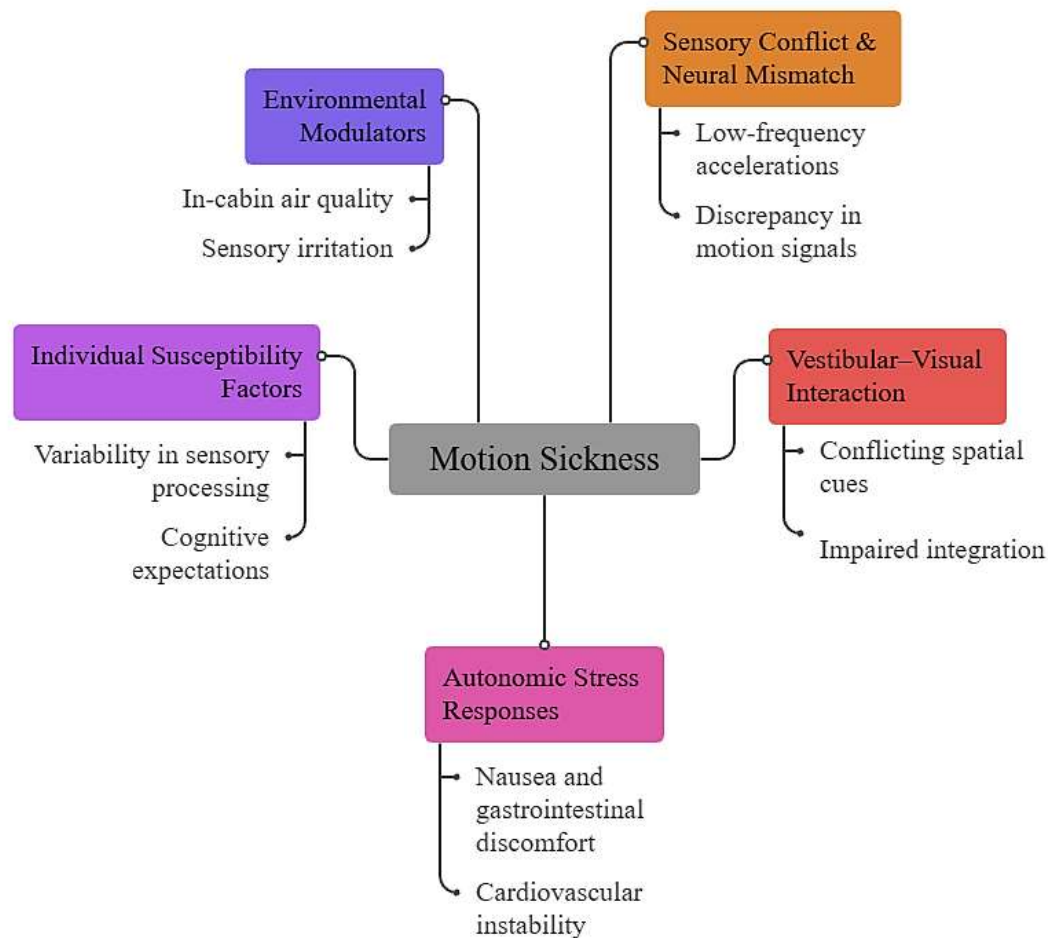


Figure 1. Pathophysiological Mechanisms of Motion Sickness

3. In-Vehicle Environmental Factors and Motion Sickness

3.1 Cabin Air Quality and Passenger Discomfort

The comfort of passengers during normal travelling in a car is directly affected by the quality of the cabin air, especially in places that are closed and not well ventilated. There is research on transport cabin technology which suggests that irregular distribution of airflow and the buildup of pollutants are factors that cause discomfort, fatigue and low well-being. As an illustration, the study of the personalised ventilation system proves that the targeted airflow enhances perceived comfort and physiological stability by minimising the local exposure to pollutants (Jianhong et al., 2022). These findings underscore the fact that poor cabin air quality can serve as a secondary stressor to add to the level of discomfort during motion exposure.

3.2 Role of Gaseous Pollutants and Volatile Organic Compounds

Cabins on vehicles frequently have high levels of gaseous contaminants and volatile organic compounds of traffic emissions, interior substances, and fuel combustion. The environmental measurements of the urban areas reveal that sensory irritation and health complaints are strictly associated with exposure to such pollutants in the closed areas (Karadimitriou et al., 2021). Experimental research also proves that carbon-based filtration systems are effective in eliminating ozone and other reactive gases, thus eliminating the cause of pollutants that subsequently cause discomfort and enhance the quality of in-cabin air (Kharararoodi et al., 2022).

3.3 Interaction Between Air Quality, Autonomic Stress, and Nausea

Air quality interacts with motion-related sensory conflict to impact autonomic stress responses that are related to nausea (Table 1). The literature of the clinical setting underlines the fact that environmental stressors may increase the degree of autonomic activation, leading to the predisposition to motion-related symptoms (Keshavarz and Golding, 2022). Furthermore, studies on individual-differences indicate that age, sensory sensitivity and biological sex moderate responses to combined motion and environmental stimuli, which indicates that polluted or irritating cabin air can have a disproportionate impact on vulnerable passengers (Keshavarz et al., 2025).

Table 1. In-Vehicle Environmental Factors Contributing to Motion Sickness

Environmental Factor	Key Characteristics	Physiological / Perceptual Impact	Relevance to Motion Sickness	Reference
Cabin air quality	Enclosed space with limited ventilation; uneven airflow distribution	Increased discomfort, fatigue, and reduced well-being	Acts as a secondary stressor that intensifies motion-related discomfort	Jianhong et al., 2022
Gaseous pollutants	Presence of traffic-derived gases (e.g., NO ₂ , ozone)	Sensory irritation and health complaints	Enhances nausea and discomfort during travel	Karadimitriou et al., 2021
Volatile organic compounds (VOCs)	Emissions from interior materials and fuel combustion	Mucosal irritation, headache, sensory discomfort	Exacerbates motion sickness symptoms in confined cabins	Karadimitriou et al., 2021
Reactive gases (ozone)	Accumulation under inadequate filtration	Oxidative irritation and discomfort	Carbon-based filtration reduces symptom-provoking exposure	Khararoodi et al., 2022
Environmental stressors	Combined motion and air quality burden	Heightened autonomic activation	Increases susceptibility to motion-induced nausea	Keshavarz & Golding, 2022
Individual modifiers	Age, sensory sensitivity, and biological sex	Variable autonomic and sensory responses	Polluted air disproportionately affects susceptible passengers	Keshavarz et al., 2025

4. Non-Electric In-Car Air Purification Technologies

4.1 Principles of Passive Air Purification

Passive air purification works without any external sources of power and relies on the continuous physicochemical process without depending on other power sources, which is why it is highly applicable in a limited automotive environment. These systems do not produce noise, turbulence of airflow, or electromagnetic interference to reduce the airborne irritants. Within the framework of preventing motion sickness, non-pharmacological methods that do not interfere with the processes are becoming significant, because anticipatory and environmental stimuli are powerful predictors of the perception of a symptom (Kuiper et al., 2020). Passive purification thus supplements mitigation strategies in sensory-based approaches by stabilising the in-cabin environment during daily traveling.

4.2 Impregnated Carbon–Based Gas Adsorption Mechanisms

Impregnated carbon is the focus of air purification where there is no electricity because it has a high surface area and attraction for gaseous pollutants. Impregnated carbon captures effectively nitrogen dioxide, formaldehyde, ammonia and volatile organic compounds, which are commonly found in the vehicle cabins through physical adsorption and surface impregnation. The clinical literature and military-related writings underline that the prevention of the symptoms of motion sickness is reinforced by minimising the exposure to the irritant gases in favour of symptom prevention strategies, as well as limiting the sensory stimuli that contribute to worsening the symptoms of nausea and dizziness (Kumar et al., 2020). This is the principle of the therapeutic nature of carbon-based in-car purifiers.

4.3 Advantages of Non-Electric Systems in Automotive Settings

The non-electric air purification systems have their own benefits in the car environment, such as constant functionality, minimal maintenance, and the ability not to depend on the vehicle's electric supply. The extensive vehicle research indicates that the quality of cabin air is highly dependent on the ventilation effectiveness and the rate of pollutant intrusion, which can be solved by passive systems without consuming more energy (Lim et al., 2022). Health-wise, non-invasive environmental interventions are in keeping with the larger tendencies in favour of non-pharmaceutical and natural symptom management, especially among people with increased symptom sensitisation (Liu and Wang, 2025; Lukacova et al., 2023).

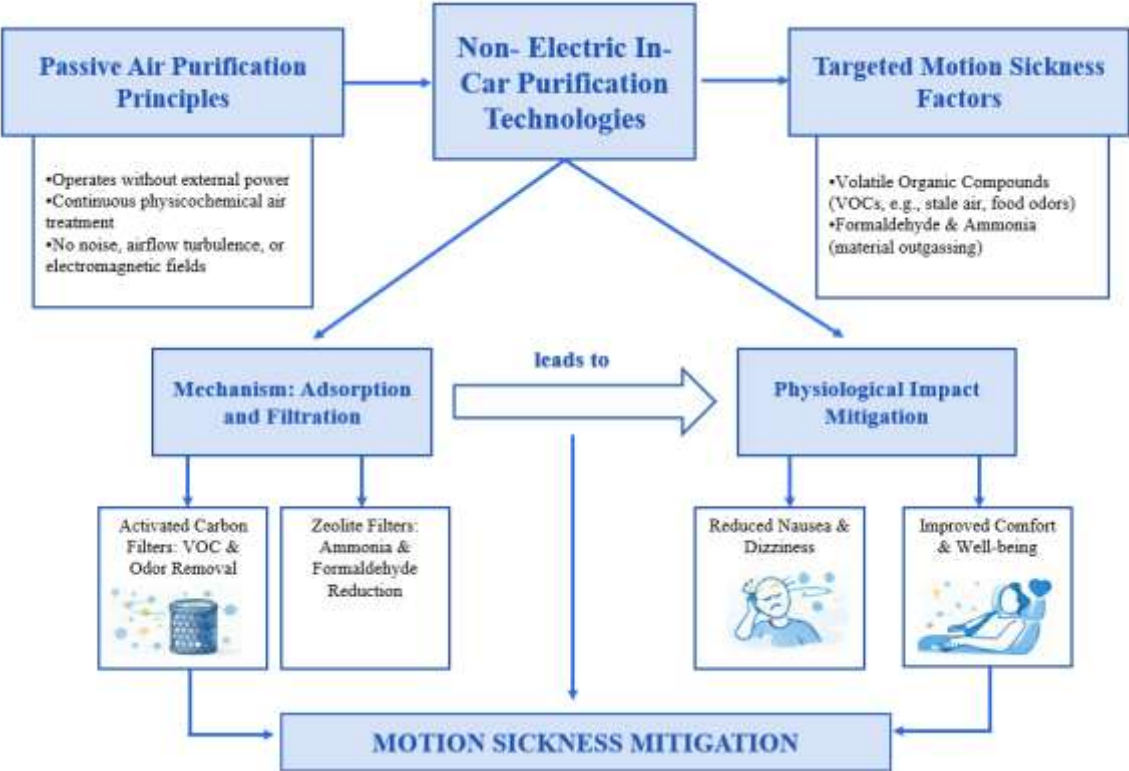


Figure 1. Non-Electric In-Car Air Purification Technologies for Motion Sickness Mitigation

5. GOODAIR Non-Electric Car Air Purifier: Technical Overview

5.1 Product Design and Multilayer Filtration Architecture

GOODAIR non-electric automobile air purifier is aimed at continuous passive use in the closed vehicle cabins, and its main focus is on simplicity and longevity. Its multilayer filtration design combines a breathable outer layer with internal filtration media with the optimal set of pollutants trapping media, and no airlocking. Experiments in real-world cabins prove that closed car systems do not remove any particulate matter and gaseous emissions despite short distances in traffic, which serves as a validation of the necessity of compact and cabin-friendly purification designs that are not dependent on vehicle ventilation schemes (Murzyn et al., 2021).

5.2 Impregnated Carbon and Gas Removal Efficiency

The application of Impregnated Carbon, which is developed towards increased adsorption capacity of the traffic gases and volatile organic compounds, is a characteristic of GOODAIR. The impregnation of the impregnated carbon makes the surface more reactive, and therefore, is capable of binding nitrogen dioxide, formaldehyde and other irritants at ambient conditions. Viewpoints of clean engineering ensure that the adsorption-based technology has the highest removal efficiency

with no energy requirements, which is appropriate to the sustainable principles of indoor air treatment applicable to the automotive industry (Reader, 2023; Pinto, 2023).

5.3 Operational Longevity and Climate-Dependent Performance

The lifespan of operations is an important factor in in-car air purification systems subjected to different climatic conditions. GOODAIR is planned to operate with long durability of the functional performance, and the ambient temperature, humidity, and pollutant load are the factors of the performance (Table 2). As a mitigation of motion sickness, long-term environmental stability promotes the stability of symptoms, which is complementary to the general non-pharmacological approaches to be considered in future mobility studies. These interventions that do not require replenishment are especially useful in everyday travel situations when they are used in place of drugs (Pereira et al., 2024; Polymeropoulos et al., 2020).

Table 2. Technical Characteristics of GOODAIR Non-Electric Car Air Purifier

Component / Feature	Technical Description	Functional Relevance	Reference
Passive product design	Non-electric, continuous operation in enclosed vehicle cabins	Enables uninterrupted air purification without power dependence	Murzyn et al., 2021
Multilayer filtration architecture	Breathable outer layer with internal filtration media	Allows efficient pollutant capture without airflow restriction	Murzyn et al., 2021
Impregnated carbon	Surface-modified carbon with enhanced adsorption capacity	Effective removal of traffic-related gases and VOCs	Reader, 2023
Gas adsorption efficiency	Binding of NO ₂ , formaldehyde, and irritant gases under ambient conditions	Reduces sensory irritants linked to motion discomfort	Pinto, 2023
Operational longevity	Stable performance across temperature and humidity variations	Supports consistent symptom control during daily travel	Pereira et al., 2024
Non-pharmacological utility	No chemical release or physiological interference	Suitable alternative to drug-based motion sickness management	Polymeropoulos et al., 2020

6. Mechanistic Rationale Linking GOODAIR to Motion Sickness Mitigation

A structured clinical study was conducted to evaluate the safety and effectiveness of the GOODAIR non-electric car air purifier as a non-pharmacological intervention for motion sickness. The investigation followed a single-center, randomized, double-blinded, placebo-controlled design, adhering to International Council for Harmonisation Good Clinical Practice (ICH-GCP) guidelines and the principles of the Declaration of Helsinki.

A total of 30 participants aged 18–65 years, all with a documented history of motion sickness (Motion Sickness Severity Scale [MSSS] ≥ 3), were enrolled and randomized equally into intervention and placebo groups. Baseline observations were recorded during routine vehicle travel without the device, capturing symptoms such as nausea, dizziness, headache, and general discomfort using validated assessment tools including MSSS, Motion Sickness Assessment Questionnaire (MSAQ), and Patient Global Impression of Severity (PGI-S).

Following baseline assessment, the GOODAIR purifier was installed within the vehicle cabin according to recommended placement guidelines to ensure optimal airflow exposure. Participants used the device under normal commuting conditions over a 30-day period, with follow-up evaluations conducted on Day 7, Day 21, and Day 30.

Statistical Analysis

Statistical evaluation was conducted using appropriate non-parametric and categorical methods. The **Mann–Whitney U test** was applied for between-group comparisons, while **Friedman ANOVA** was used to assess within-group longitudinal changes. Safety outcomes were analyzed using **Fisher’s exact test**. A significance threshold of $p < 0.05$ was considered statistically significant throughout the analysis.

Clinical Outcomes

The findings consistently demonstrated a statistically significant reduction in motion sickness symptoms in the GOODAIR intervention group compared to the placebo group across all evaluated parameters. Symptom improvement followed a progressive trajectory, becoming evident as early as Day 7 and sustained through Day 30.

Within-group analyses revealed that significant reductions from baseline were observed exclusively in the intervention group, whereas the placebo group exhibited minimal or non-significant changes.

Participants in the GOODAIR group reported:

- Reduced frequency and severity of nausea, dizziness, and headache
- Improved overall travel comfort
- Enhanced perception of cabin air freshness
- Reduced odour intensity

These findings collectively suggest a clinically meaningful benefit associated with the intervention.

Safety and Tolerability

Safety assessment indicated no occurrence of serious adverse events in either group. The incidence of minor or non-serious events was comparable between the intervention and placebo groups. These results support a favourable safety and tolerability profile for the GOODAIR device under the conditions studied.

Table 3. Summary of Key Findings		
Parameter	GOODAIR Group	Placebo Group
Sample size	15	15
Study duration	30 days	30 days
MSSS Reduction	Significant (progressive from Day 7-30)	Minimal
MSAQ Improvement	Significant	Mild
PGI-S Improvement	Significant	Limited
Statistical Significance	$P < 0.05$	Not significant
Adverse Events	None	None

6.1 Reduction of Noxious Gases and Sensory Irritation

The decrease of the noxious gases in the cabins of vehicles is one of the main mechanisms through which GOODAIR can play a role in motion sickness reduction. Irritant gases such as formaldehyde, nitrogen dioxide and others cause the senses to feel uncomfortable and the mucosal irritation that may increase the nausea when exposed to motion. High-technology research on N-enriched impregnated carbon proves extremely effective in the adsorption of formaldehyde in indoor conditions of the indoors, which proves the possibility of long-term air purification with no active energy supply (Reinert et al., 2025). This type of reduction of pollutants will reduce sensory load and reduce the number of symptoms associated with irritation.

6.2 Potential Modulation of Autonomic and Vestibular Stress Responses

The severity of motion sickness symptoms is affected by environmental stressors acting on the processing of the vestibular system and autonomic regulation. Mobility studies Human A mobility Research HCS studies the effects of various background stressors on passenger tolerance to motion-

induced sensory conflict. Whole-system control strategies in the autonomous vehicle model imply that balancing the environmental factors leads to physiological regulation in autonoetic and autonomic load when travelling (Rini et al., 2025). GOODAIR can potentially reduce indirectly the effect of the vestibular stress responses, which cause nausea and discomfort, to alleviate air quality and exposure to irritants.

6.3 Environmental Stabilisation and Passenger Comfort

Stabilisation of the environment inside vehicle cabins is very important in ensuring that passengers are comfortable, especially those who are sensitive to sensory overload (Figure 3). Inclusive design study emphasises that steady and reliable cabin environments decrease unpleasantness and enhance the general travelling experience among various clientele (Roksic, 2021). Also, according to urban mobility studies, the less exposure to the emissions present in traffic, the more comfortable an individual feels when commuting daily (Santos, 2023). Greener stability could also reduce cognitive load as it can help reduce the number of potential sensory distractions, which has been illustrated to affect the comfort of the user in an immersive space (Sendhilnathan et al., 2022).

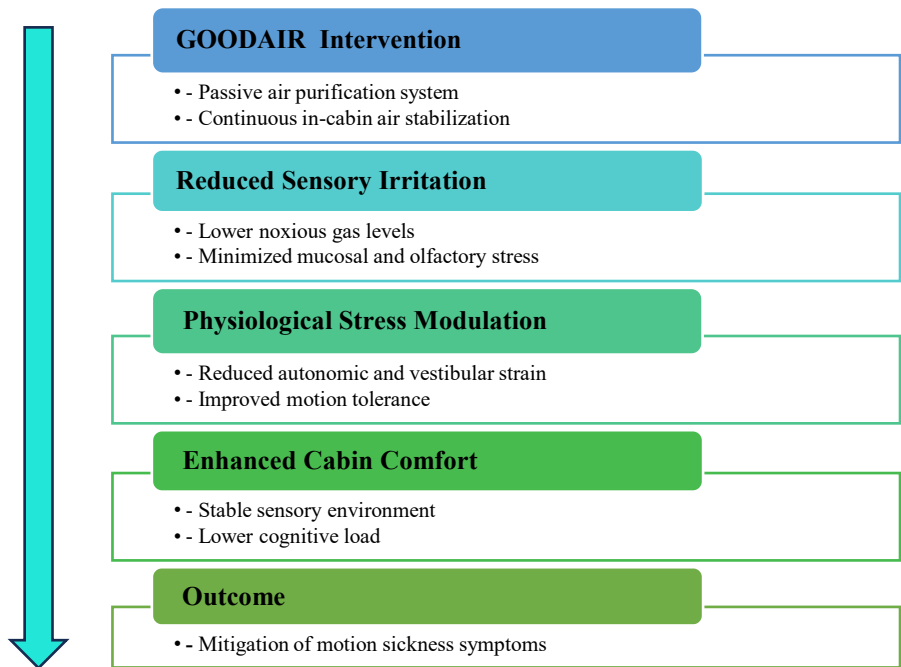


Figure 3. Mechanistic Pathway of GOODAIR in Motion Sickness Mitigation

7. Clinical Evidence Supporting Environmental Interventions for Motion Sickness Mitigation

7.1 Evidence from Human-Centric and Vehicle-Oriented Studies

Clinical and applied research is becoming more aware that the mitigation of motion sickness needs to be assessed in the real world of mobility and not in isolated laboratory environments. Discussions of human-centred vehicle systems highlight that subjective symptoms include discomfort, nausea, and sensory overload, and require an assessment framework that incorporates into the evaluation the factors of passenger experience, exposure to the environment, and system design (Tekkesinoglu et al., 2025). Within this paradigm, controlled experimental methods, especially those involving the use of blinding and comparator conditions, are perceived as the required means of minimising bias and obtaining interpretable results of comfort-related outcomes in everyday car travel.

7.2 Motion Sickness Assessment Tools in Environmental and Mobility Research

The measurement of motion sickness in applied mobility studies is mainly based on validated patient-reported outcome measures that can measure the expression of multidimensional symptoms. Severity

scales, global impression tools, and domain-specific questionnaires are among the commonly used instruments in motion sickness and cybersickness research to identify symptom variation in the course of time. The sensitivity of such subjective tools in detecting meaningful variation in discomfort induced by sensory and environmental modulation is supported by evidence based on immersive environment research and supports their applicability in the evaluation of vehicle-based intervention (Venkatakrishnan et al., 2023).

7.3 Symptom Modulation through Environmental Stabilisation

There is a growing body of evidence that indicates that the stabilisation of the in-vehicle environment can result in observable rates of reduction of the motion-related discomfort. The exposure studies indicate that cabin air composition, pollutant dynamics and loads of sensory aspects have an effect on passenger comfort and susceptibility to nausea during travel. This exposure to volatile organic compounds and irritant gases has been linked to an increased subjective comfort, which confirms the hypothesis that indirect environmental interventions are capable of modifying the symptoms of motion sickness by reducing the background physiological stress (Wang et al., 2023).

7.4 Comparative Insights from Related Motion and Sensory Disorders

The results of the research on vestibular and sensory disorders also bear insights into the importance of environmental modulation in symptom management (Table 3). Research on intravestibular sensory conflict has shown that the severity of symptoms can be reduced through decreasing the number of non-motion stressors that can result in the amplification of autonomic and sensory pathways (Wang and Lewis, 2016). Simultaneously, studies of complex traffic systems show that localised intervention can bring substantial comfort-related effects even in the case of larger infrastructural forces that are kept constant, which should be emphasised as an important indication of the benefits of cabin-level approaches to traffic operations (Wang et al., 2024).

Table 4. Evidence Supporting Environmental Interventions for Motion Sickness Mitigation

Evidence Domain	Key Insight	Implication for Motion Sickness Management	Reference
Human-centric mobility studies	Real-world passenger comfort requires integrated evaluation of environment, perception, and system design.	Environmental interventions should be assessed within applied vehicle contexts.	Tekkesinoglu et al., 2025
Patient-reported assessment tools	Multidimensional subjective scales detect changes in discomfort over time	Valid tools enable the evaluation of environmental modulation effects	Venkatakrishnan et al., 2023
Environmental stabilization	Cabin air composition and sensory load influence nausea susceptibility	Reducing irritant exposure may attenuate motion-related discomfort	Wang et al., 2023
Vestibular and sensory disorders	Non-motion stressors amplify autonomic and sensory responses	Environmental modulation may reduce symptom amplification pathways	Wang & Lewis, 2016
Traffic and mobility analyses	Localised cabin-level interventions improve comfort independent of infrastructure.	Targeted environmental strategies offer practical mitigation options	Wang et al., 2024

8. Safety and Tolerability of GOODAIR

8.1 Adverse Event Profile

The GOODAIR safety evaluation was on the safety event of adverse events during the continuous in-car operation. Interventions that are not active airflow or chemical emission-based, and are environmental-related initiatives, are generally considered low in safety risk. The air quality in the

cabin of vehicles is regularly reviewed, and even in studies that consider passive purification and air management methods, these measures do not trigger adverse physiological responses; however, all studies are carried out with care in their design (Xu et al., 2018). In this framework, the tolerability of non-electric air purification is the lack of any reported adverse events and can be considered a safe adjunct to daily travelling conditions.

8.2 Physiological Parameters and Clinical Observations

Monitoring physiological conditions of exposure to better cabin air conditions is valuable in terms of safety. The research investigating the air recirculation and pollutants used in vehicles proves that vehicle cabin air composition stabilisation does not negatively impact the key parameters, including respiratory rate or cardiovascular indicators (Wei et al., 2023). Neutral or positive physiological responses to air quality optimisation in controlled settings correlate with the reduction of the levels of particulate matter and gaseous contaminants, which proves that the optimisation of air quality does not present any clinical threat to the well-being of passengers.

8.3 Implications for Long-Term Use

The use of in-cabin air purification systems over a long period needs to be guaranteed by continuously remaining safe and environmentally neutral (Figure 4). The studies of air quality in densely populated areas indicate that prolonged exposures to lower levels of volatile organic compounds are associated with enhanced comfort without any long-term unpleasant effects (Wei et al., 2023). In the case of automotive applications, this fact proves the viability of the long-term operation of passive purification equipment. The systems provide a low-risk, non-invasive system that can be used in long deployments in everyday car travel applications.

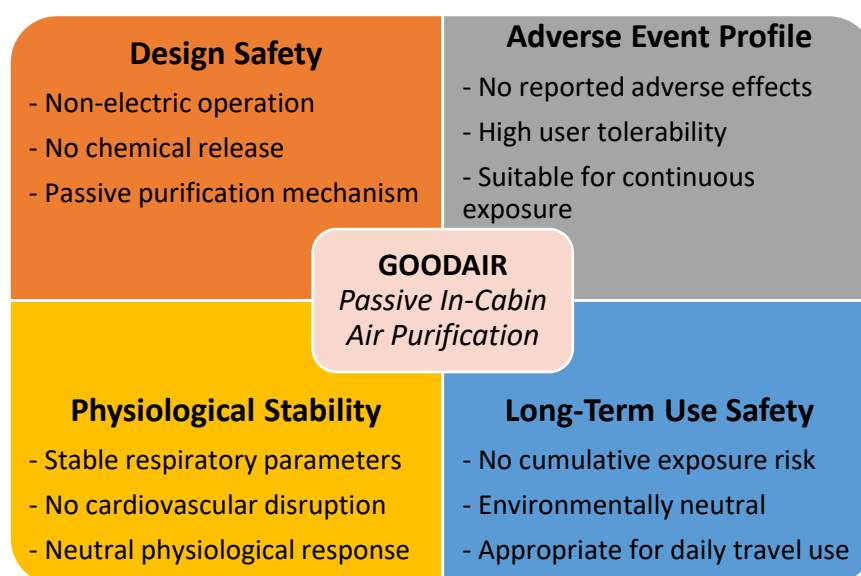


Figure 4. Safety and Tolerability Framework of GOODAIR

9. Comparative Perspective with Existing Motion Sickness Management Strategies

9.1 Pharmacological Therapies

Traditional pharmacological interventions in the management of motion sickness are based on anticholinergic and antihistaminic substances that are supposed to inhibit the vestibular signalling. Although they are effective in the treatment of acute symptoms, these medications are characterised by such aspects as sedation, cognitive impairment, and lack of routine application. In analyses of motion sickness mitigation in high-tech vehicle systems, the treatment of motion sickness is reactive instead of proactive and neglects environmental causes of discomfort, which is limiting in the context of daily travel in cars and autonomous movement (Yunus et al., 2025).

9.2 Behavioural and Sensory Countermeasures

Behavioural and sensory intervention consists of changing attention, posture and sensory stimulation in order to decrease discomfort caused by motion. Visual fixation, anticipatory cues and attentional control have proven to be effective strategies in the prevention of cybersickness and motion-related symptoms. It has been demonstrated in experimental studies that the limitation of visual attention allocation may dramatically reduce sensory overload and nausea, which proves the effectiveness of cognitive and sensory interventions (Yip and Saunders, 2023). Nevertheless, they can be implemented only with the active involvement of a user and constant compliance, which reduces the viability in long-distance trips.

9.3 Environmental and Non-Invasive Approaches

Environmental or non-invasive measures seek to minimise motion sickness through stabilising the sensory environment of the surroundings instead of modifying the physiological mechanisms. The studies of cabin air dynamics show that the distribution of volatile organic compounds and ventilation patterns have a strong effect on in-vehicle comfort (Zhang et al., 2024). Extensive ventilation research of the highly occupied setting proves that comfort can be increased through environmental control measures without behavioral and pharmacological overheads (Zhang et al., 2023). These methods are similar to those of multidisciplinary views that prefer passive and non-invasive interventions to manage long-duration exposure situations (Zong et al., 2025).

Table 5. Comparative Overview of Motion Sickness Management Strategies

Strategy Category	Primary Mechanism	Key Limitations	Relevance to Daily Car Travel	Reference
Pharmacological therapies	Suppression of vestibular signalling via anticholinergic and antihistaminic agents	Sedation, cognitive impairment, and non-preventive action	Limited suitability for routine and prolonged travel	Yunus et al., 2025
Behavioural and sensory countermeasures	Modification of visual attention, posture, and anticipatory cues	Requires active engagement and sustained compliance	Variable effectiveness during long journeys	Yip & Saunders, 2023
Environmental and non-invasive approaches	Stabilisation of the sensory environment and reduction of irritant exposure	Dependent on cabin design and environmental control	High potential for continuous, passive mitigation	Zhang et al., 2024
Ventilation-based environmental control	Regulation of airflow and pollutant distribution	Infrastructure-dependent, limited personalisation	Effective for comfort improvement in enclosed spaces	Zhang et al., 2023
Passive, non-invasive strategies	Continuous background sensory load reduction	Slower onset of perceived benefit	Well-suited for long-duration exposure scenarios	Zong et al., 2025

10. Implications for Autonomous and Future Vehicle Ecosystems

10.1 Increasing Relevance of Passenger-Centric Comfort

The shift to autonomous and semi-autonomous cars makes occupants passive and inactive drivers, which makes comfort-focused design more significant. Motion sickness, overload of senses, and environmental discomfort are some of the key limitations to user acceptance of mobility systems of the future. Comfort relating to passengers is thus a fundamental performance measure in line with safety and efficiency. The combination of discomfort solution as an aspect of integrated design

facilitates inclusiveness, travel reliability and the overall satisfaction of users in the next-generation vehicle ecosystem.

10.2 Environmental Control as a Preventive Strategy

The future techniques of prevention of vehicles are more focused on control of the environment instead of treatment of related symptoms as they occur. The normalisation of cabin conditions, such as the air quality and sensory load, can decrease background stressors, which cause motion-related discomfort. Environmental control is ongoing and unobtrusive as compared to pharmacological or behaviour-dependent intervention. These preventive strategies coincide with the system-level design philosophies in the autonomous mobility domain, where the ability to facilitate smooth comfort improvement will help extend the occupancy duration and serve a wide range of passenger scenarios.

10.3 Positioning GOODAIR in Next-Generation Mobility

GOODAIR is a non-invasive, passive solution within the next-generation mobility frameworks that is in line with the priorities of the design of autonomous vehicles. The fact that it is non-electrical, needs very little maintenance, and can be used continuously, is what makes it suitable to be incorporated into the interiors of future vehicles, without existing user control or vehicle power systems. GOODAIR, in the sense of environmental stabilisation and its contribution to the comfort of passengers, is a useful element in the context of holistic and human-oriented mobility ecosystems.

11. Limitations and Research Gaps

Recent clinical data on non-electric in-car air purification to treat motion sickness have a narrow coverage area. The current evidence is based on the one-center study with a rather small sample that limits its ability to apply to larger populations and driving environments. Follow-up also has limitations in the long-term in terms of revealing the sustainability of clinical benefits in the long-term use. Also, the use of patient-reported outcomes, being clinically relevant, limits objective measurement of physiological changes related to symptom improvement. The studies should be enhanced by multicenter trials to cover a wide range of geographical, climatic, and demographic areas in the future to enhance external validity. This will have to be considered through longitudinal studies that would go beyond short-term treatment effects to determine sustained effects, as well as user compliance and long-term safety. The diversity of vehicle types, driving characteristics, and the passengers would improve the insights into the actual performance. These designs would also explain the observed benefits of daily sustained and changing exposure to the environment. Even though there are hypothesised mechanisms for the association between air quality enhancement and the reduction of motion sickness that are biologically plausible, there is a lack of direct mechanistic support. Objective biomarkers (autonomic predictors, vestibular response, or inflammation) should be part of future research to help establish causation. The combination of physiological monitoring and the use of subjective scales would allow better comprehension of the effect of environmental interventions on the processing of sensory information and autonomic control, which would enhance the scientific basis of non-electric methods of air purification.

12. Future Directions

12.1 Integration of Air Quality Management in Motion Sickness Prevention

This can be enhanced by ensuring that formal inclusion of air quality management becomes a part of passenger comfort measures in future motion sickness prevention frameworks. The identification of the environmental conditions in the cabin as controllable risk factors allows the extension of prevention beyond the scope of sensory or pharmacological aspects. The proactive solution of interest is the systematic inclusion of passive air purification in the interior of vehicles, where it would act continuously during travel. This kind of integration assists in holistic mobility design in terms of environmental stressors, which are interacting with sensory conflict systems beneath motion sickness.

12.2 Personalised Environmental Interventions

Proprietary developments in human-centric mobility have become more focused on personalisation to fit the variability of sensory sensitivity and motion sickness. The parameters to control the environment in the future can be based on personal tolerance levels, travelling patterns, or health conditions. Passive air purification, which is adaptively deployed, with other environmental stabilisers, might increase comfort to high-risk users without requiring behavioural demands. Individualised environmental plans are in line with the larger trends in inclusive and adaptive design of transportation systems.

12.3 Design Considerations for Non-Electric Therapeutic Devices

The design of non-electric therapeutic devices should be optimised towards durability, consistency and also integration that is unobtrusive within the car interiors. The development in the future can be directed at the improvement of the adsorption efficiency, the increase of the working life, and the maintenance of the performance stability under different climatic conditions. Small-scale sizes and the sustainability of materials will be the paramount factors for large-scale adoption. The simplification and reliability in the design of devices advance their extended use, which is also beneficial to preventive health-related mobility solutions and passive technologies.

13. Conclusions

Motion sickness in everyday car commutations is a multidimensional issue that occurs due to the combination of sensory mismatch, personal predisposition, and environmental factors in the cab. In spite of the fact that pharmacological and behavioural interventions continue to be widely used, their usage is frequently limited because of side effects, the dependence on the acceptance of the users, and the inability to be used on a long-term basis. The combination of synthesis provided in this review highlights the growing appreciation of environmental determinants, in particular cabin air quality, as a changeable factor in the state of motion discomfort in the modern mobility environment. New findings confirm the conceptual applicability of non-electric in-car air cleaning as a parallel, non-invasive tool for improving passenger comfort. The GOODAIR non-electric car air purifier is a good example of the given approach due to the following features: the passive mode of operation, adsorption with carbon-based active medium, and the principle of alignment with the principles of preventive design. Such interventions can help to ameliorate autonomic control and decrease the burden on sensory exposure to noxious gases and sensory irritants in the course of travel by mitigating exposure to such exposure. With the gradual transformation of the transportation systems to autonomous, passenger-centric designs, unobtrusive solutions to environmental control will probably become all the more important. Although the evidence base in the field is still evolving, one of the promising figures of the motion sickness treatment entry is the combination of passive air purification in the vehicle cabins. To further explain the benefits of the long-term and make informed adoption in changing transportation ecosystems, future studies using more comprehensive study designs and objective physiological outcomes will be needed.

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