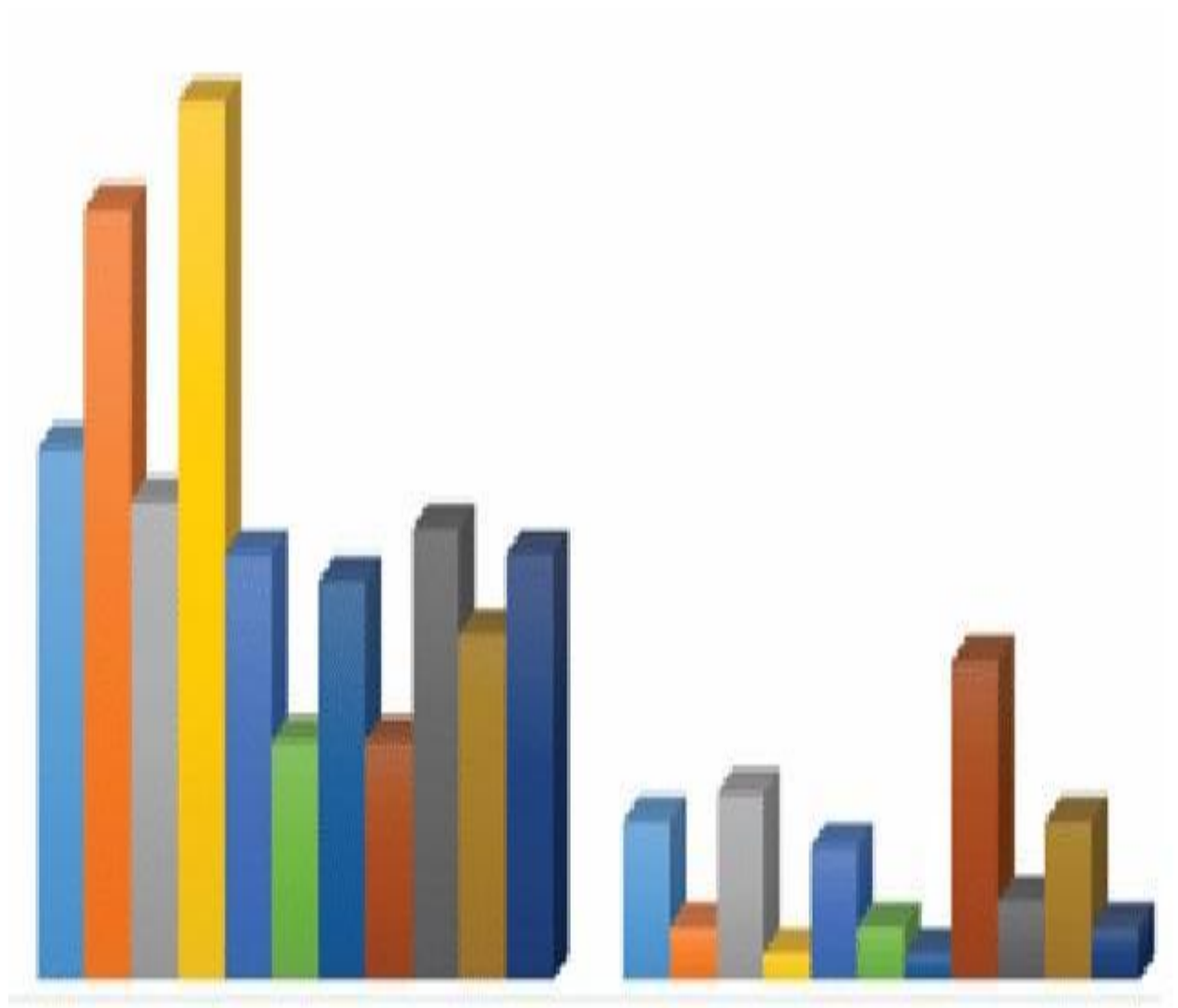


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Research Article

Navigating IoT-Driven Indoor Environmental Quality in Residential Interiors: A Phenomenological Study

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ABSTRACT

The integration of Internet of Things (IoT) technologies into residential interiors has significantly transformed the monitoring and management of Indoor Environmental Quality (IEQ). This study adopts a phenomenological approach to explore how occupants experience IoT-driven environments, emphasising the interplay between objective environmental data and subjective perception. Drawing on secondary qualitative data from peer-reviewed literature, the research synthesises insights from environmental psychology, smart home technologies, and human-centred design. The findings reveal that IoT systems enhance environmental awareness through real-time data, facilitate behavioural adaptation, and contribute to improved comfort and well-being. However, they also introduce challenges related to data interpretation, privacy concerns, and technological dependency. The study highlights the emergence of a hybrid experiential framework in which digital interfaces mediate human-environment interaction. By integrating phenomenology with theories of technology acceptance and environmental psychology, the research provides a comprehensive understanding of IoT-driven IEQ. It concludes that effective implementation requires a balance between technological innovation and user-centred design, ensuring that smart residential environments remain responsive, inclusive, and ethically grounded.

Keywords: internet of things, indoor environmental quality, phenomenology, smart homes, environmental perception, human-centred design, residential interiors

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1. Introduction

In contemporary society, the quality of indoor environments has emerged as a central concern in residential design, public health, and sustainability discourse. Individuals spend an estimated 85-90% of their time indoors, making Indoor Environmental Quality (IEQ) a critical determinant of physical health, psychological well-being, and overall quality of life (Klepeis et al., 2001; Sundell, 2004). IEQ encompasses a multidimensional framework that includes indoor air quality, thermal comfort, visual comfort, and acoustic conditions. These dimensions collectively shape human experiences within built environments and influence behavioural patterns, cognitive performance, and long-term health outcomes (Bluyssen, 2010; Mujan et al., 2019).

Historically, IEQ assessments have relied on objective measurements, such as temperature readings, humidity levels, and concentrations of indoor pollutants. While these metrics provide valuable insights into environmental performance, they often fail to capture the subjective and experiential dimensions of human comfort. Research in environmental psychology has demonstrated that occupants' perceptions of comfort frequently diverge from standardised measurements, highlighting the need for more integrated approaches that consider both objective data and subjective experience (Frontczak & Wargocki, 2011; Nicol & Humphreys, 2002).

The advent of the Internet of Things (IoT) has introduced a transformative paradigm in the monitoring and management of indoor

environments. IoT refers to a network of interconnected devices embedded with sensors, software, and communication capabilities that enable the collection and exchange of data in real time (Atzori et al., 2010). In the context of residential interiors, IoT-enabled systems facilitate continuous monitoring of environmental variables such as temperature, humidity, carbon dioxide (CO₂) levels, particulate matter (PM_{2.5}), light intensity, and noise levels. These systems provide occupants and building managers with actionable insights, allowing for dynamic adjustments that optimise indoor conditions (Zhang et al., 2023; Tsang et al., 2024).

The integration of IoT into residential environments aligns with the broader evolution of smart homes, which aim to enhance comfort, efficiency, and sustainability through automation and data-driven decision-making. Smart thermostats, air quality sensors, adaptive lighting systems, and automated ventilation systems are increasingly becoming commonplace in residential settings. These technologies not only improve environmental performance but also empower occupants to actively engage with their surroundings (Balta-Ozkan et al., 2013; Wilson et al., 2017).

Despite these technological advancements, the human dimension of IoT-driven IEQ remains underexplored. Much of the existing literature focuses on technical performance, system architecture, and energy efficiency, often neglecting how occupants experience and interpret these technologically mediated environments. This gap is particularly significant given that the effectiveness of IoT

systems depends not only on their technical capabilities but also on user engagement, acceptance, and behavioural adaptation (Davis, 1989; Marikyan et al., 2019).

A phenomenological approach offers a valuable framework for addressing this gap by emphasising lived experience and subjective interpretation. Rooted in the philosophical traditions of Husserl (1970) and Heidegger (1962), phenomenology seeks to understand how individuals perceive and make sense of their environments. In the context of IoT-driven IEQ, this approach enables a deeper exploration of how occupants interact with digital interfaces, interpret environmental data, and integrate technological feedback into their daily routines.

Moreover, the intersection of IoT and IEQ raises important ethical and social considerations, including data privacy, technological dependency, and digital literacy. While IoT systems offer significant benefits, they also introduce new challenges related to data security and user autonomy. Understanding these dimensions is essential for developing human-centred design strategies that prioritise both technological innovation and occupant well-being (Zuboff, 2019; Perera et al., 2015).

This study aims to explore IoT-driven IEQ in residential interiors through a phenomenological lens, focusing on the lived experiences of occupants as mediated by smart technologies. By synthesising secondary qualitative data from existing literature, the research seeks to answer the following questions:

- How do IoT systems influence occupants' perception of indoor environmental quality?
- In what ways do occupants interact with and respond to IoT-generated environmental data?
- What are the implications of IoT-driven IEQ for residential design and occupant well-being?

By addressing these questions, the study contributes to an emerging body of knowledge that integrates technology, human experience, and environmental design. It underscores the importance of moving beyond purely technical perspectives to embrace a more holistic understanding of indoor environments, one that recognises the complex interplay between objective conditions and subjective experience.

2. Literature Review

Indoor Environmental Quality (IEQ) is a multifaceted construct that integrates physical, chemical, biological, and psychological dimensions of indoor environments. It is widely recognised as a critical factor influencing occupant health, comfort, and productivity (Bluyssen, 2010). The four primary components of IEQ, indoor air quality, thermal comfort, visual comfort, and acoustic comfort, are interrelated and often interact in complex ways.

Indoor air quality (IAQ) is one of the most extensively studied components of IEQ, given its direct impact on respiratory health. Exposure to pollutants such as volatile organic compounds (VOCs), particulate matter (PM), and carbon dioxide can lead to

adverse health outcomes, including asthma, allergies, and sick building syndrome (Sundell, 2004; Jones, 1999). Thermal comfort, defined as the condition of mind that expresses satisfaction with the thermal environment, is influenced by factors such as temperature, humidity, air velocity, and personal variables (Fanger, 1970; Nicol & Humphreys, 2002).

Visual comfort relates to lighting conditions, including illumination levels, glare, and access to natural light. Adequate lighting is essential for visual performance, circadian rhythm regulation, and psychological well-being (Boyce, 2014). Acoustic comfort, on the other hand, concerns the control of noise levels and sound quality within indoor environments. Excessive noise can lead to stress, reduced concentration, and decreased productivity (Kang et al., 2016).

Recent research emphasises the need for integrated IEQ frameworks that consider the interactions among these components rather than treating them in isolation. For instance, increasing ventilation to improve air quality may affect thermal comfort and energy consumption, highlighting the importance of holistic approaches (Rohde et al., 2019).

2.1 Evolution of IoT Technologies in Indoor Environmental Monitoring

The integration of IoT technologies into indoor environmental monitoring represents a significant shift from traditional, static assessment methods to dynamic, data-driven approaches. IoT systems utilise networks of sensors and connected devices to collect, transmit, and analyse environmental data in real time (Atzori et al., 2010).

Early environmental monitoring systems relied on standalone sensors and manual data collection, which limited their ability to capture temporal variations. In contrast, IoT-enabled systems provide continuous monitoring, enabling more accurate and comprehensive assessments of indoor conditions (Zhang et al., 2023). These systems often incorporate cloud computing and edge computing technologies to process large volumes of data efficiently (Perera et al., 2015).

IoT-based IEQ systems typically include sensors for temperature, humidity, CO₂, particulate matter, light intensity, and noise levels. Advanced systems integrate machine learning algorithms to predict environmental conditions and optimise building performance (Tsang et al., 2024). For example, smart thermostats can learn occupants' preferences and adjust temperature settings automatically, while air quality sensors can trigger ventilation systems when pollutant levels exceed predefined thresholds.

The application of IoT in residential settings has expanded rapidly in recent years, driven by the growing popularity of smart home technologies. These systems not only enhance comfort and convenience but also contribute to energy efficiency and sustainability (Balta-Ozkan et al., 2013). However, the effectiveness of IoT systems depends on their usability and the extent to which occupants engage with the technology.

2.2 Human-Centred Approaches and Environmental Perception

While technological advancements have improved the measurement and control of IEQ, there is increasing recognition of the importance of human-centred approaches. Environmental perception plays a crucial role in determining occupant satisfaction, as individuals interpret and respond to environmental conditions based on their preferences, expectations, and experiences (Frontczak & Wargocki, 2011).

Studies have shown that occupants' perceptions of comfort are influenced not only by physical conditions but also by contextual factors such as control, adaptation, and cultural norms (Nicol & Humphreys, 2002). For instance, individuals who have control over their environment, such as the ability to adjust temperature or lighting, tend to report higher levels of satisfaction, even if the objective conditions are not optimal.

IoT systems have the potential to enhance environmental perception by providing real-time feedback and enabling greater control. However, they can also create new challenges, such as information overload and reliance on automated systems. Understanding how occupants interact with these technologies is essential for designing effective and user-friendly systems (Marikyan et al., 2019).

2.3 Phenomenological Perspectives on Indoor Environments

Phenomenology offers a valuable lens for exploring the experiential dimensions of indoor environments. Unlike positivist approaches that prioritise objective

measurement, phenomenology focuses on subjective experience and meaning-making (Husserl, 1970; Heidegger, 1962).

In the context of IEQ, a phenomenological perspective emphasises how individuals perceive and interpret environmental conditions in their daily lives. This approach recognises that comfort is not merely a physical state but a lived experience shaped by sensory perception, emotional responses, and social context.

The integration of IoT technologies introduces a new layer of complexity to this experience, as environmental perception becomes mediated by digital interfaces and data visualisation. For example, an occupant's perception of air quality may be influenced not only by sensory cues but also by data displayed on a smartphone application.

2.4 Technology Acceptance and Behavioural Adaptation

The adoption and effectiveness of IoT-driven IEQ systems depend on user acceptance and behavioural adaptation. The Technology Acceptance Model (TAM) posits that perceived usefulness and ease of use are key determinants of technology adoption (Davis, 1989).

In residential contexts, occupants are more likely to engage with IoT systems if they perceive them as beneficial and easy to use. Factors such as user interface design, accessibility, and trust play a critical role in shaping user experiences (Marikyan et al., 2019).

Behavioural adaptation is another important aspect of IoT-driven IEQ. Real-time feedback can encourage occupants to adopt behaviours that improve environmental quality, such as opening windows, adjusting thermostats, or reducing energy consumption. However, sustained behavioural change requires ongoing engagement and motivation.

2.5 Research Gaps and Future Directions

Despite significant advancements in IoT and IEQ research, several gaps remain. First, there is a lack of qualitative studies that explore occupants' lived experiences of IoT-driven environments. Second, existing research often focuses on technical performance rather than human experience. Third, there is a need for interdisciplinary approaches that integrate insights from engineering, architecture, psychology, and sociology.

Future research should prioritise user-centred design, incorporating occupant feedback into the development of IoT systems. Additionally, ethical considerations such as data privacy and security must be addressed to ensure the responsible use of IoT technologies.

3. Theoretical Framework

This study is grounded in an interdisciplinary theoretical framework that integrates phenomenology, environmental psychology, and the Technology Acceptance Model (TAM). These perspectives collectively provide a comprehensive lens for understanding how occupants experience and interact with IoT-driven Indoor

Environmental Quality (IEQ) systems in residential interiors. By combining philosophical, psychological, and technological theories, the framework enables an in-depth exploration of both subjective experience and behavioural engagement.

3.1 Phenomenology and Lived Experience

Phenomenology serves as the primary theoretical foundation of this research, emphasising the study of lived experience and the ways individuals perceive and interpret their environments. Originating in the works of Husserl (1970), phenomenology seeks to uncover the essence of experience by examining how phenomena appear to consciousness. Husserl's concept of intentionality suggests that consciousness is always directed toward something, meaning that perception is inherently relational and context-dependent.

Heidegger (1962) expanded phenomenology by introducing the concept of *being-in-the-world*, which highlights the inseparability of individuals from their environments. According to Heidegger, human existence is fundamentally embedded in spatial and social contexts, making environmental experience an integral part of everyday life. In residential interiors, this implies that IEQ is not merely a set of measurable variables but a lived reality shaped by sensory perception, emotional responses, and habitual practices.

Applying phenomenology to IoT-driven IEQ reveals how digital technologies mediate environmental experience. For instance, the presence of real-time data on air quality or

temperature can alter how occupants perceive their surroundings. Rather than relying solely on sensory cues, individuals increasingly interpret environmental conditions through digital interfaces, creating a hybrid experiential space that combines physical and virtual elements. This aligns with Merleau-Ponty's (2012) notion of embodied perception, which emphasises the role of the body in shaping experience.

Furthermore, phenomenology allows for the exploration of temporal dimensions of experience. IoT systems introduce continuous monitoring, enabling occupants to perceive environmental changes over time. This dynamic awareness contrasts with traditional static perceptions of indoor environments and highlights the evolving nature of comfort and well-being.

3.2 Environmental Psychology and Human-Environment Interaction

Environmental psychology provides a complementary perspective by focusing on the reciprocal relationship between individuals and their physical surroundings. This field examines how environmental conditions influence behaviour, cognition, and emotional states (Gifford, 2014). In the context of IEQ, environmental psychology underscores the importance of subjective perception, personal control, and adaptive behaviour.

One key concept in environmental psychology is the notion of environmental appraisal, which refers to how individuals evaluate and respond to their surroundings. Research has shown that occupants' satisfaction with indoor environments is

influenced not only by physical conditions but also by psychological factors such as expectations, preferences, and perceived control (Frontczak & Wargocki, 2011). For example, individuals who can adjust temperature or lighting tend to report higher levels of comfort, even under suboptimal conditions.

IoT technologies have the potential to enhance environmental control by providing occupants with real-time information and automated systems. However, they also introduce new dynamics in human-environment interaction. Automated systems may reduce the need for manual intervention, potentially diminishing occupants' sense of control. Conversely, interactive interfaces can empower users by enabling informed decision-making.

The adaptive comfort model, developed by Nicol and Humphreys (2002), is particularly relevant in this context. It suggests that comfort is a dynamic process influenced by behavioural, physiological, and psychological adaptation. IoT systems can facilitate this adaptation by providing feedback that encourages occupants to modify their behaviour, such as adjusting ventilation or clothing. This highlights the role of technology as both a mediator and a catalyst in human-environment interaction.

3.3 Technology Acceptance Model (TAM) and User Engagement

The Technology Acceptance Model (TAM), developed by Davis (1989), provides a theoretical basis for understanding how individuals adopt and use new technologies. TAM posits that two primary factors,

perceived usefulness and perceived ease of use, determine users' attitudes toward technology and their intention to use it.

In the context of IoT-driven IEQ systems, perceived usefulness relates to the extent to which occupants believe that the technology enhances their comfort, health, and well-being. Perceived ease of use refers to the simplicity and accessibility of the system, including user interfaces and data visualisation tools. Studies have shown that user-friendly interfaces and clear data representation significantly increase engagement with smart home technologies (Marikyan et al., 2019).

Trust is another critical factor influencing technology acceptance, particularly in systems that collect and process personal data. Concerns about privacy and data security can hinder the adoption of IoT technologies, even when their functional benefits are evident (Perera et al., 2015). Therefore, understanding user perceptions of trust and risk is essential for the successful implementation of IoT-driven IEQ systems.

TAM also highlights the importance of behavioural intention, which bridges the gap between perception and action. In residential settings, occupants must not only accept IoT technologies but also actively engage with them to achieve optimal outcomes. This includes interpreting data, making adjustments, and integrating technology into daily routines.

3.4 Integrative Theoretical Perspective

By integrating phenomenology, environmental psychology, and TAM, this

study adopts a holistic approach to understanding IoT-driven IEQ. Phenomenology provides insights into lived experience, environmental psychology explains behavioural responses, and TAM elucidates technology adoption and engagement.

This integrative framework acknowledges that IEQ is both a physical and experiential phenomenon, shaped by the interplay of environmental conditions, technological mediation, and human perception. It also recognises that the success of IoT systems depends on their ability to align with users' needs, preferences, and experiences.

4. Research Methodology

This study adopts a qualitative research design grounded in phenomenological inquiry. The primary objective is to explore how individuals experience IoT-driven IEQ in residential interiors. Given the exploratory nature of the research and its focus on subjective experience, a qualitative approach is most appropriate (Creswell & Poth, 2018).

Rather than collecting primary data through interviews or observations, this study utilises secondary data derived from existing literature. This approach allows for the synthesis of diverse perspectives and findings, providing a comprehensive understanding of the phenomenon under investigation. Secondary qualitative analysis is particularly valuable in emerging fields such as IoT and smart environments, where a growing body of research offers rich insights into user experiences (Johnston, 2017).

4.1 Data Sources and Selection Criteria

The study draws on peer-reviewed journal articles, systematic reviews, conference proceedings, and academic reports related to IoT, IEQ, and human-environment interaction. Key databases include Scopus, Web of Science, ScienceDirect, SpringerLink, and IEEE Xplore.

The selection of sources was guided by the following inclusion criteria:

- Studies focusing on IoT applications in indoor environmental monitoring
- Research addressing residential or indoor environments
- Studies incorporating human experience, perception, or behaviour
- Publications in English within the last 10-15 years

Exclusion criteria included studies focusing solely on technical system design without consideration of user experience, as well as non-peer-reviewed sources.

4.2 Data Collection Strategy

A systematic literature review approach was employed to identify relevant studies. The process was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021). Keywords used in the search included:

- “IoT AND indoor environmental quality”
- “smart homes AND occupant experience”

- “indoor air quality AND user perception”
- “phenomenology AND built environment”

The initial search yielded a large number of studies, which were subsequently screened based on titles, abstracts, and full texts. Relevant studies were then selected for in-depth analysis.

4.3 Data Analysis Method

The study employs thematic analysis as the primary method of data analysis. Thematic analysis is a flexible qualitative method used to identify, analyse, and interpret patterns within data (Braun & Clarke, 2006). The analysis followed six key steps:

- Familiarisation with the data through repeated reading
- Generation of initial codes related to key themes
- Searching for patterns and relationships among codes
- Reviewing and refining themes
- Defining and naming themes
- Producing a coherent narrative

Themes were interpreted through a phenomenological lens, focusing on how occupants experience and make sense of IoT-driven environments. This approach allows for the integration of multiple perspectives while maintaining a focus on lived experience.

4.4 Trustworthiness and Rigour

To ensure the credibility and reliability of the findings, the study adopts established criteria for qualitative research rigour, including

credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

- **Credibility** was enhanced through the use of multiple data sources and triangulation of findings.
- **Transferability** was addressed by providing detailed descriptions of the context and research process.
- **Dependability** was ensured through a systematic and transparent methodology.
- **Confirmability** was achieved by maintaining an audit trail of data sources and analytical decisions.

4.5 Ethical Considerations

As the study is based on secondary data, it does not involve direct interaction with human participants and therefore does not require ethical approval. However, ethical considerations related to academic integrity and proper citation were strictly observed. All sources were appropriately cited in accordance with APA (7th ed.) guidelines.

Additionally, the study acknowledges broader ethical issues associated with IoT technologies, including data privacy, surveillance, and user consent. While these issues are not directly investigated in the methodology, they form an important context for interpreting the findings (Mannan & Farhana, 2026).

4.6 Limitations of the Methodology

Despite its strengths, the methodology has certain limitations. The reliance on secondary data may limit the depth of insight into individual experiences, as the study depends on existing interpretations rather than

firsthand accounts. Furthermore, variations in study design, context, and quality across sources may affect the consistency of findings.

Nevertheless, the use of a systematic and rigorous analytical approach helps to mitigate these limitations and ensures a comprehensive understanding of the research topic.

5. Findings and Analysis

The thematic analysis of secondary qualitative data reveals several interconnected dimensions through which IoT-driven Indoor Environmental Quality (IEQ) systems shape occupants' lived experiences in residential interiors. These findings are interpreted through a phenomenological lens, emphasising how individuals perceive, interpret, and respond to technologically mediated environments. Five major themes emerged: enhanced environmental awareness, behavioural adaptation and agency, hybridisation of objective and subjective comfort, emotional and psychological impacts, and challenges of technological mediation.

5.1 Enhanced Environmental Awareness and Sensory Augmentation

One of the most significant impacts of IoT-driven IEQ systems is the transformation of occupants' environmental awareness. Traditional indoor environments rely primarily on human sensory perception, such as feeling warm or cold, noticing stale air, or experiencing glare. However, IoT systems augment these sensory experiences by

providing real-time quantitative data on environmental conditions.

This phenomenon can be understood as a form of *sensory extension*, where digital interfaces act as additional perceptual tools. For example, occupants may become aware of elevated CO₂ levels or particulate matter concentrations that are otherwise imperceptible. Studies have shown that such data-driven awareness can significantly influence how individuals perceive indoor environments (Tsang et al., 2024; Zhang et al., 2023).

From a phenomenological perspective, this shift represents a reconfiguration of perception. According to Merleau-Ponty (2012), perception is embodied and shaped by interaction with the environment. IoT systems introduce a mediated layer of perception, where data visualisation becomes part of the experiential field. As a result, occupants no longer rely solely on bodily sensations but also interpret environmental conditions through digital representations.

This enhanced awareness can lead to more informed decision-making, as occupants gain insights into patterns and fluctuations in IEQ. For instance, real-time air quality data may prompt individuals to open windows, activate air purifiers, or adjust ventilation systems. However, it also raises questions about the reliability of sensory experience versus technological data, potentially leading to a dependence on digital feedback.

5.2 Behavioural Adaptation and the Reconfiguration of Agency

IoT-driven IEQ systems play a critical role in shaping occupant behaviour by providing

continuous feedback and enabling automated control. The findings indicate that occupants often modify their behaviours in response to real-time data, demonstrating a dynamic interplay between environmental conditions and human actions.

This aligns with the adaptive comfort model, which posits that individuals actively adjust their behaviour to achieve thermal comfort (Nicol & Humphreys, 2002). IoT systems facilitate this process by offering actionable information, such as temperature trends or humidity levels, thereby supporting adaptive strategies like adjusting clothing, altering ventilation, or modifying thermostat settings.

However, the introduction of automation complicates the notion of agency. While IoT systems empower occupants by providing information and control, they can also reduce direct engagement through automated decision-making. For example, smart thermostats and automated ventilation systems may operate independently of user input, potentially diminishing occupants' sense of control.

This duality reflects a tension between *empowerment* and *delegation*. On one hand, occupants gain access to sophisticated tools that enhance their ability to manage indoor environments. On the other hand, reliance on automated systems may lead to passive engagement, where individuals become less attentive to environmental conditions.

The Technology Acceptance Model (Davis, 1989) helps explain this dynamic by highlighting the importance of perceived usefulness and ease of use. When IoT systems are intuitive and provide clear

benefits, occupants are more likely to engage actively. Conversely, complex or opaque systems may discourage interaction, leading to reliance on automation.

5.3 Hybridisation of Objective and Subjective Comfort

A key finding of this study is the emergence of a hybrid understanding of comfort that integrates objective measurements with subjective perception. Traditional IEQ frameworks often treat comfort as a measurable condition, defined by standardised parameters such as temperature ranges or air quality thresholds (Fanger, 1970). However, the findings suggest that IoT systems blur the boundaries between objective and subjective dimensions of comfort.

Occupants frequently interpret environmental data in relation to their personal experiences, creating a feedback loop between measurement and perception. For instance, a sensor may indicate that the temperature is within an optimal range, yet an occupant may still feel uncomfortable due to factors such as clothing, activity level, or personal preference.

This discrepancy highlights the limitations of purely quantitative approaches to IEQ. As noted by Frontczak and Wargocki (2011), occupant satisfaction is influenced by a range of contextual factors that cannot be fully captured by numerical data. IoT systems, while providing valuable insights, must therefore be integrated with user feedback to achieve a more holistic understanding of comfort.

The hybridisation of comfort also reflects broader shifts in how individuals relate to technology. Rather than replacing subjective experience, IoT systems interact with and reshape it, creating a multidimensional framework in which data and perception coexist.

5.4 Emotional and Psychological Impacts of IoT-Driven Environments

Beyond physical comfort, IoT-driven IEQ systems have significant implications for emotional and psychological well-being. The findings indicate that real-time environmental feedback can influence occupants' sense of security, control, and satisfaction.

On the positive side, access to environmental data can enhance feelings of safety and reassurance. For example, knowing that air quality is being continuously monitored may reduce anxiety related to pollution or health risks. Similarly, automated systems that maintain stable environmental conditions can contribute to a sense of comfort and predictability (Wilson et al., 2017).

However, the constant availability of data can also lead to *information anxiety*. Occupants may become overly concerned with fluctuations in environmental parameters, even when these variations are within acceptable ranges. This phenomenon reflects the psychological impact of data saturation, where excessive information can lead to stress and decision fatigue.

From a phenomenological perspective, these emotional responses are integral to the lived

experience of IoT-driven environments. Heidegger's (1962) concept of *attunement* suggests that individuals are always emotionally oriented toward their surroundings. IoT systems, by altering how environments are perceived, also influence emotional states.

5.5 Challenges of Technological Mediation: Privacy, Trust, and Dependency

While IoT systems offer numerous benefits, the findings highlight several challenges associated with technological mediation. These include concerns about privacy, trust, and dependency.

Privacy concerns arise from the collection and storage of personal data, particularly in residential settings where occupants expect a high degree of confidentiality. IoT systems often gather detailed information about environmental conditions and user behaviour, raising questions about data ownership and security (Perera et al., 2015; Zuboff, 2019).

Trust is closely linked to these concerns. Occupants must trust that IoT systems are accurate, reliable, and secure. Any perceived lack of transparency or control can undermine user confidence and hinder adoption.

Dependency is another critical issue. As occupants become accustomed to IoT-driven environments, they may rely increasingly on technology for environmental management. This dependency can reduce individuals' ability to interpret and respond to environmental conditions independently,

potentially diminishing their environmental awareness over time.

6. Discussion

The findings of this study offer significant insights into the evolving relationship between humans, technology, and indoor environments. By interpreting these findings through the integrated theoretical framework, this section explores the broader implications for theory, practice, and future research.

6.1 Reframing Indoor Environmental Quality as a Lived Experience

One of the central contributions of this study is the reconceptualisation of IEQ as a lived experience rather than a purely technical construct. Traditional approaches to IEQ emphasise measurable parameters, often overlooking the subjective and experiential dimensions of comfort (Bluyssen, 2010).

The findings demonstrate that IoT systems fundamentally alter how occupants perceive and engage with their environments. By providing real-time data, these systems transform IEQ into an interactive and dynamic phenomenon. This aligns with phenomenological perspectives, which emphasise the importance of perception, embodiment, and meaning-making in shaping human experience (Merleau-Ponty, 2012).

This reframing has important implications for research and practice. It suggests that IEQ assessments should incorporate both objective measurements and subjective feedback, recognising that comfort is a

multidimensional and context-dependent phenomenon.

6.2 The Mediating Role of Technology in Human-Environment Interaction

The study highlights the role of IoT technologies as mediators between occupants and their environments. Rather than directly experiencing environmental conditions, individuals increasingly rely on digital interfaces and data visualisation tools.

This mediation creates a *hybrid environment* in which physical and digital elements are intertwined. While this can enhance awareness and control, it also introduces new complexities in how environments are perceived and understood.

From an environmental psychology perspective, this shift underscores the importance of designing technologies that support meaningful interaction. User interfaces should be intuitive, transparent, and aligned with occupants' needs and preferences (Gifford, 2014).

6.3 Implications for Human-Centred Residential Design

The findings underscore the need for human-centred design approaches in the development of IoT-driven residential environments. Designers must consider not only the technical performance of IEQ systems but also their impact on user experience.

Key considerations include:

- **Usability:** Systems should be easy to understand and operate.

- **Personalisation:** Technologies should adapt to individual preferences.
- **Transparency:** Data should be presented in a clear and meaningful way.
- **Control:** Occupants should have the ability to override automated systems.

By prioritising these factors, designers can enhance user engagement and satisfaction, ensuring that IoT technologies contribute positively to residential living.

6.4 Behavioural and Social Implications

The study also highlights the behavioural and social implications of IoT-driven IEQ systems. Real-time feedback can encourage environmentally responsible behaviours, such as reducing energy consumption or improving ventilation.

However, the effectiveness of these interventions depends on user engagement and motivation. As noted by Marikyan et al. (2019), sustained behavioural change requires not only technological support but also social and cultural factors.

Additionally, the integration of IoT technologies into residential environments may influence social dynamics, as shared spaces and resources are managed through digital systems. This raises questions about equity, accessibility, and inclusivity, particularly in contexts where technological resources may be unevenly distributed.

6.5 Ethical Considerations and Future Directions

The ethical implications of IoT-driven IEQ systems are a critical area for future research. Issues such as data privacy, surveillance, and user autonomy must be addressed to ensure the responsible use of technology.

The concept of *surveillance capitalism* (Zuboff, 2019) highlights the potential risks associated with data-driven technologies, particularly in terms of data exploitation and loss of privacy. In residential contexts, these concerns are especially significant, as homes are traditionally considered private spaces.

Future research should explore strategies for balancing technological innovation with ethical considerations, including the development of privacy-preserving technologies and transparent data governance frameworks.

6.6 Limitations and Research Implications

While this study provides valuable insights, it is important to acknowledge its limitations. The reliance on secondary data may limit the depth of analysis, as the findings are based on existing interpretations rather than firsthand accounts.

Future research should incorporate primary qualitative methods, such as interviews and ethnographic studies, to capture richer and more nuanced perspectives. Additionally, longitudinal studies could provide insights into how occupants' experiences evolve.

7. Conclusion

This study has explored the evolving landscape of Indoor Environmental Quality (IEQ) in residential interiors through the lens of Internet of Things (IoT) technologies and phenomenological inquiry. By synthesising secondary qualitative data, the research highlights how IoT-driven systems are not merely technical tools for environmental monitoring but transformative agents that reshape how occupants perceive, interpret, and interact with their living environments.

One of the central conclusions of this study is that IoT technologies significantly enhance environmental awareness by providing real-time, data-driven insights into indoor conditions. This increased awareness enables occupants to engage more actively in managing their environments, fostering adaptive behaviours that improve comfort, health, and energy efficiency. However, this engagement is not uniform and is influenced by factors such as usability, trust, and perceived usefulness, as explained by the Technology Acceptance Model (Davis, 1989).

The study also underscores the emergence of a hybrid understanding of comfort, where objective environmental measurements intersect with subjective perception. This finding challenges traditional IEQ frameworks that rely solely on standardised metrics and emphasises the need for more holistic approaches that incorporate human experience. From a phenomenological perspective, comfort is revealed as a dynamic and context-dependent phenomenon shaped by sensory, cognitive, and emotional processes (Merleau-Ponty, 2012).

At the same time, the research identifies critical challenges associated with IoT-driven environments, including privacy concerns, data overload, and technological dependency. These issues highlight the importance of ethical considerations in the design and implementation of smart home technologies. Ensuring data security, transparency, and user autonomy is essential for fostering trust and promoting widespread adoption.

From a practical standpoint, the findings have important implications for residential design and policy. Designers and developers must adopt human-centred approaches that prioritise usability, personalisation, and occupant control. Integrating user feedback into the development of IoT systems can enhance their effectiveness and ensure that they align with the diverse needs and preferences of occupants.

In conclusion, IoT-driven IEQ represents a paradigm shift in how indoor environments are understood and managed. By bridging the gap between technology and human experience, this study contributes to a more nuanced and interdisciplinary understanding of residential environments. Future research should build on these insights by incorporating primary empirical data and exploring long-term user experiences, ultimately advancing the development of sustainable, inclusive, and responsive smart living environments.

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