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Dynamism in the context of views out: A literature review

Yunni Cho [a,*], Caroline Karmann [a,b], Marilyne Andersen [a]

[a] Laboratory of Integrated Performance in Design (LIPID), School of Architecture, Civil and Environmental Engineering (ENAC), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

[b] Laboratory of Architecture and Intelligent Living, Institute for Building Design and Technology (IEB), Department of Architecture, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

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ABSTRACT

Previous studies have shown that access to a satisfactory view to the outside with sufficient daylight is essential for building occupants' health and well-being. It has also been suggested that certain features of visual content improve view-out quality, such as horizontal stratification, natural landscapes, distant features, and diversity of visual elements. Additionally, having movement and changes in viewing content has been shown to further strengthen building occupants' engagement and connectivity to their surrounding environment. The objective of this paper is to review the literature on the dynamism of the view content and the inclusion of this criterion in the current metrics of view evaluation. Our review revealed a need for further research on view dynamism, especially focusing on testing different types, speeds, and scales of movement on view quality assessment. It also showed that more comprehensive view evaluation frameworks should be developed to accurately preserve the dynamic qualities of window views in experimental settings. While many view rating metrics have acknowledged the importance of movement, this criterion is to date ignored or only poorly included in existing metrics, which further highlights the need of learning more about this topic.

1. Introduction

1.1. Role of windows

Dynamic changes within buildings are driven by two key factors - daylight and window views. Daylight, as a dynamic light source, plays a critical role in shaping the illumination and visual perception of an interior environment [1]. Unlike artificial light sources, daylight constantly changes throughout the day and year, influenced by latitude and local weather conditions. These regional nuances in our experience of daylight contribute to diverse subjective perceptions of daylit environments, as demonstrated in studies by Refs. [2,3]. By introducing a captivating interplay of variable shadow patterns and fluctuating levels of brightness, this ever-changing natural light fosters positive visual and temporal qualities for building occupants [4].

View-out, defined as what can be seen by building occupants from a given aperture, satisfies fundamental human needs to keep track of our location, time, weather conditions, and activities outside the building [5–7]. By providing a sense of connection to the outside, particularly to nature, access to an outdoor view has been shown to provide a significant array of benefits to a space's inherent qualities, such as enhancing physiological and psychological well-being [8], increasing recovery speed of surgery patients [9,10] and workspace satisfaction [11]. Previous studies suggest that even a very small window can satisfy our innate desire to be close to nature by providing continuous contact with the outside world [12].

Both view-out and daylight conditions provide numerous salutogenic benefits, including increased alertness, mood, relaxation, job satisfaction, work productivity, and cognitive performance [4,13–16,]. Daylight also presents ideal light properties for humans - through its intensity, spectrum, and timing - in modulating melanopsin responses in the intrinsically photosensitive retinal ganglion cells (ipRGCs), which are responsible for synchronizing circadian rhythms and can have a significant influence on one's sleep quality and immune system [8]. A study from Ref. [17] on Swedish office workers showed that increased daylight exposure correlates with better sleep quality and positive mood ratings. Exposure to natural environments and daylight through a high-quality view-out is thus critical for building occupants' health and well-being.

1.2. Defining view quality

View quality, defined as "the quality of the visual connection to the

* Corresponding author. École Polytechnique Fédérale de Lausanne (EPFL), EPFL ENAC IA LIPID, LE 1 113, Bâtiment LE, Station 18, 1014, Lausanne, Switzerland.
E-mail address: yunni.cho@epfl.ch (Y. Cho).

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outdoors that satisfies building occupants," is inherently subjective, observer-dependent, and influenced by its surrounding contexts [18]. In order to successfully incorporate view into a building design practice, researchers have proposed multiple design standards and metrics to quantify and assess the quality of a window view. A new framework, the View Quality Index (VQI) was recently proposed by Ref. [18] to define view quality in terms of three variables, namely view content, access, and clarity, based on an extensive literature review on existing design standards, building certifications, view quality assessment frameworks and their limitations. These three primary variables are described as follows [18]:

- the visual 'content' of what can be seen from a window, influenced by factors such as natural features, horizontal stratification, content distance, dynamic features, spatial frequency, and fractal patterns
- the amount of view an occupant can 'access' from the viewing position, which depends on view angle, viewing distance, window-to-wall ratio, viewing direction, and of course, on the human visual field
- the 'clarity' of the view affected by the choice of window glazing and shading systems, and thereby also the resulting window mullions, frames, and general geometric properties.

Furthermore, research has shown that certain shared visual features in the viewing content generally lead to a higher view-out quality and increased occupant satisfaction. These features include horizontal stratification [19–22], distant features [5,23,24], natural landscape [25–29], diversity of visual elements [8,30], and people and traffic [31,32]. This suggests that building occupants often prefer views with higher information content, as they provide a better connection to the world outside and access to environmental information as well as more psychological benefits [33]. However, unlike the monotonous indoor environment, views are dynamic. They provide different visual content to what is seen within the interior space through changes in sensory stimuli [33].

1.3. Defining dynamism in view content

Motion signals can be interpreted as spatiotemporal gradients, i.e., positional changes of luminant patterns across space and time [34]. We comprehend the form of a moving object by observing the difference in the spatial arrangement of its luminance, color, texture, and movement patterns relative to its background [34]. Although there is no consensus on a unified definition, dynamism in view content can be defined as the outdoor elements that cause visible changes in a view [18]. The outdoor environment, which constructs the view content, is dynamic and constantly changes over time, and the perception of movement is crucial for one's visual understanding of an environment.

Movement within the viewing content provides information about time passing, weather changes, or objects moving closer or further away from the observer. Indeed, the dynamic visual features of a view-out not only refer to more immediate moving elements such as people, traffic, or tree foliage but also involve changing daylight conditions that depend on the time of day, weather, and seasonal settings [18]. The daylight transmitting the view continuously changes in intensity, color, direction, and diffuseness, which can improve the perceived view quality while creating an appealing interior environment. Movements and temporally changing daylight conditions are, therefore, both equally important for our holistic understanding of an environment and for our appraisal of a view-out. In fact, as views occur from the transmission of visual information through windows when daylight reflects off outdoor surfaces, view-out and daylight are interdependent and cannot be considered as separate entities [18]. Hence, daylight can be defined both as the carrier of an outdoor view as well as the dynamic source of illuminance transmitted through the window [33].

The VQI index accounts for such research findings by defining view content in terms of nature and urban features, horizontal stratification, content distance, and dynamic movements as the key attributes [18]. However, unlike the other content features, there is a lack of research knowledge on dynamic movement in view content, and the extent to which dynamism influences the view quality remains unclear. This paper aims to address this gap by providing a review on dynamism in view-out content and in view-out rating metrics to pave the way for future research needs in this field.

2. Review methodology

The main objective of this literature review is to gather a wide range of existing studies that investigated the influence of dynamism in view content on perceived view quality. Through this literature review, we also aimed to understand the current state-of-the-art in the dynamism of view-out for view quality assessment and to identify knowledge gaps in view dynamism through applicable findings from other related fields (beyond building science) that could lead to new research interests and directions. To achieve this, we performed an extensive search for eligible literature with an emphasis on finding studies with a dedicated focus on dynamic movement and temporal changes in window views.

The initial step was to query Google Scholar with keyword searches, namely "view-out", "window view", "view content", "view quality", "dynamic movements", "movement in view-out", "view dynamism", "movement/motion perception", "motion detection", and "daylight changes". Using the articles identified through this approach as a starting point, direct backward and forward citation tracking was used to search for additional relevant articles under the same topic until the pool of articles no longer expanded toward further studies that were at least of some relevance. To make sure all applicable scholarly articles are included in this review, the same search method was also performed in Scopus and Web of Science databases. Studies were ultimately selected for a deeper analysis in this review only when they met all three selection criteria listed below.

Selection Criteria:

1. Publication written in or translated into English, to ensure that it is accurately interpreted;
2. Published in a peer-reviewed journal, a peer-reviewed conference paper, a Ph.D. thesis, or as a book edited by an established publisher;
3. Explicitly addressing dynamism and/or its assessment in the proposed research methodology or the discussed findings.

3. Review outcomes

In total, 51 studies published between 1973 and 2023 were judged eligible and were therefore included in this review. To systematically gather the breadth of literature from different disciplines, we organized this review into three sections. The included studies were first classified based on whether their findings provide useful insight for understanding dynamism from the field of vision science (Section 3.1), environmental psychology (Section 3.2), and building science (Section 3.3). The review is structured to first present knowledge from other academic disciplines that broaden our perspective of dynamism in views out, followed by an analysis of studies that directly investigated the effect of dynamism in view content. After establishing the current state-of-the-art on the topic of view dynamism through findings from a broader (vision science, environmental psychology) to a more narrowly focused (view-out appraisal in building science) perspective, we evaluated view rating metrics that incorporate dynamism in view content to provide an overview of how the view dynamism is currently being integrated as part of the building design workflow (Section 4.1). Finally, the recommendations for further research are discussed (Section 4.2).

3.1. Dynamism in vision science

Insights from vision science research have significantly enhanced our understanding of motion perception and factors that shape our interpretation of movement, uncovering the underlying mechanisms that enable us to distinguish and interpret various forms of motion. Such knowledge has substantial significance to view-out research, emphasizing essential parameters and movement categories that need to be considered to accurately represent moving elements in window views. Table 1 summarizes the 15 studies discussed in this section and their potential relevance to view dynamism.

The human visual system has a remarkable ability in detecting relative motion. When presented with a complex scene featuring a moving object, the object may appear initially invisible to the observer, yet the observer immediately becomes aware of its location once the movement begins, without requiring conscious effort. This phenomenon implies the involvement of spatial selective attention in our motion perception [35]. A pioneering study by Ref. [35] greatly advanced our comprehension of the relationship between motion and visual attention by demonstrating that abrupt onsets capture attention. The researchers discovered that participants exhibited an enhanced capacity to promptly and accurately detect items that appeared suddenly, as opposed to those introduced gradually. Building on this foundation, Ref. [36] added a layer of complexity to this assertion by clarifying that it is not the motion itself that captures attention, but rather the emergence of a new perceptual object through motion. The authors challenged the commonly held belief that motion automatically captures attention in a stimulus-driven manner through experiments involving various types of motion, such as oscillation, looming, and nearby moving contours. The results of their study showed that motion effectively directs attention only when it predicts the target location. Their findings also illustrated that attention is captured through motion by segregating an element from its background, a process that occurs after the motion has commenced, thus dismissing the possibility that attention is solely captured by a salient figure-to-ground organization. Subsequently, Ref. [37] expanded this framework by revealing that attention can be captured not only by abrupt onsets and new objects, but also by translating and looming stimuli. Their research emphasized the behavioral significance of these stimuli, which indicate to an observer the potential need for immediate action. New objects, sudden movements, and looming objects all possess a sense of behavioral urgency and effectively capture attention. This narrative was further supported by Ref. [38] that highlighted the power of feature changes in capturing attention, especially in moments of temporal calm, thus emphasizing the need to understand both the spatial and temporal dimensions of movement detection.

Drawing upon the knowledge of motion detection and attentional mechanisms, several studies have explored the intricate processes that govern our visual motion perception. Ref. [39] introduced models that represent motion as a singular pattern in a three-dimensional space, with dimensions being x, y, and time. These models incorporate linear filters oriented in space-time and tuned to spatial frequency, where the velocity of motion corresponds to a three-dimensional orientation within this space. This conceptualization of motion established a framework for understanding key aspects of motion perception, including continuous and apparent motion perception. Ref. [40] reinforced these models by confirming the existence of motion detection mechanisms that are selectively attuned to spatial frequencies, orientations, and temporal frequencies. Meanwhile, Ref. [41] questioned these models by featuring the human observers' ability to perceive apparent motion in non-Fourier stimuli that lacked second-order correlations. Their findings suggested that our current understanding of motion processing might be incomplete, underscoring the need to investigate higher-order spatiotemporal correlations involved in motion perception. Successive detailed investigations by Ref. [42],[43] , and [44] have further advanced our understanding of visual motion

Table 1
Summary table of studies from the field of vision science, which provide useful insights into the detection of movement.

Publication	Relation to view dynamism	Insights
[35]	Motion and visual attention	Found that the abrupt onset captures attention through an experiment investigating the impact of temporal discontinuity on visual search by presenting a display in which one item had a sudden appearance while others gradually revealed themselves
[36]	Motion and visual attention	Three experiments were conducted to challenge the common belief that motion captures attention in a stimulus-driven fashion. Results suggest that motion can guide attention efficiently when it is predictive of target location but does not capture attention when it is unpredictive of target location
[37]	Motion and visual attention	Discovered that translating and looming stimuli capture attention, similar to the sudden appearance of new objects or changes in luminance contrast, while receding stimuli do not draw attention
[38]	Motion and visual attention	Demonstrated that feature changes can be equally effective in capturing attention as the introduction of new objects, but only if they occur during a period of temporal calm, and found that both feature changes and new objects are less effective in capturing attention when they coincide with other display changes
[39]	Visual motion detection and processing mechanisms	Proposed a model for human motion mechanisms using linear filters in space-time and spatial frequency, which generate motion energy measurements through squared and summed outputs
[40]	Visual motion detection and processing mechanisms	Indicated that the motion system contains mechanisms that are selective for different spatial frequencies and orientations, with a wide range of preferred frequencies and temporally tuned detectors
[41]	Visual motion detection and processing mechanisms	Challenged conventional Fourier mechanisms and low-level feature extraction in existing models by showcasing the capacity of human observers to perceive apparent motion in novel motion stimuli possessing distinctive spatiotemporal correlations
[42]	Visual motion detection and processing mechanisms	Presented a thorough investigation of visual motion processing dynamics, highlighting human visual system adaptation to statistical regularity in natural scenes, with a specific emphasis on optimizing causal information and examining the interaction between eye movements and visual scenes
[43]	Visual motion detection and processing mechanisms	Offered a detailed exploration of visual motion detection, encompassing its biological significance and the neural processes associated with both local and global encodings of motion information
[44]	Visual motion detection and processing mechanisms	Provided a comprehensive overview of motion detection in the retina, explaining the neural encoding of direction selectivity in retinal outputs and their capacity to capture both directional and nondirectional motion, along with the intermediate circuitry responsible for this tuning
[45]	Apparent motion	Presented various theories on the perception of apparent motion in the retina and brain and introduced a novel theory that suggests the perception of

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Table 1 (*continued*)

Publication	Relation to view dynamism	Insights
		apparent motion is governed by the rapid extraction of salient features and the application of built-in laws of motion during early visual processing
[46]	Apparent motion	Introduced a new perspective challenging prevailing viewpoints regarding the existence of apparent motion by suggesting that it is compatible with the current understanding of temporal experience rooted in direct realism
[47]	Motion speed perception	Revealed that human perception of speed is influenced by contrasts, with the average higher-contrast grating requiring a 35% decrease in speed to match the speed of a lower-contrast grating and that this effect is more significant when the stimuli are presented simultaneously rather than sequentially
[48]	Motion speed perception	Demonstrated that perceived duration can be distorted across sensory modalities, with visual stimuli having a stronger impact on auditory temporal perception than vice versa, indicating the presence of multisensory interactions in subjective time distortions
[49]	Motion speed perception	Found that the main factor influencing the perceived duration of a moving object is its speed of stimulus, rather than temporal or spatial frequency, indicating a substantial involvement of higher-level motion processing in the brain

processing dynamics. These studies have shed light on various aspects of motion detection, including the interactions between eye movements and motion processing, the biological significance of motion perception, and the neural encoding of direction selectivity.

Research within the sphere of apparent motion has also diversified our understanding of visual motion processing. The term "apparent motion" is here used to describe the process by which our brain seamlessly bridges the gaps between rapidly presented static images, creating the illusion of smooth, uninterrupted motion, despite the absence of any actual movement [45]. Investigations conducted by Ref. [45] into this phenomenon revealed that our visual system reacts to contextual cues, perceiving motion through quick extraction of salient features and the utilization of inherent laws of motion. This suggests that low-level visual processing has the ability to guide our perception of apparent motion during the initial stages of visual processing. From a philosophical angle, Ref. [46] put forth that apparent motion is compatible with a direct realism viewpoint on temporal experience. The author stressed the significance of differentiating between apparent and real motion, as apparent motion consists solely of stationary spots of light without any physically moving entity. Moreover, studies on perception of motion speed have yielded critical insights. Works by Refs. [47,48] highlighted the influence of contrast and multisensory interactions on subjective time distortions. Their studies illustrated how visual stimuli mold our perception of time, demonstrating that increased contrast in visual input can lead us to perceive movement as occurring at a faster pace. Further emphasizing the impact of stimulus speed on our perception. Ref. [49] underscored the importance of a moving object's speed in determining our perceived duration of the object's motion.

In conclusion, the findings from vision science research have shown our attentiveness to motion, particularly when it signals behavioral urgency through sudden onsets, emerging objects, and looming stimuli. Additionally, studies on motion detection mechanisms have revealed the complex representation of motion as patterns in a three-dimensional space, with specific sensitivities to spatial and temporal frequencies. Investigations into apparent motion and speed perception have further highlighted the role of contextual cues and low-level visual processing in our ability to perceive motion, with factors such as contrast and multisensory interactions playing an important role. Understanding the attentional saliency of different types of motion, the distinction between apparent and real motion, the speed of motion, and relative contrast levels provide a useful framework for classifying different movement types observed in a given view content. Hence, these insights from the field of vision science hold profound implications for view-out research and contribute to a deeper and more nuanced understanding of how we perceive and interact with the dynamic visual world around us.

3.2. Dynamism in environmental psychology

Research in the field of environmental psychology has helped us understand how movement plays a pivotal role in shaping our cognitive responses to our surroundings, fostering a sense of connectedness to the environment and promoting awareness of the passing of time. These findings have significant implications for view-out research, emphasizing the importance of considering movement in viewing content to gain a better understanding of human perception. Table 2 summarizes the 18 studies discussed in this section and their potential relevance to view dynamism.

Motion perception is crucial for our three-dimensional visual perception and environmental awareness, as it informs us about our location and physical boundaries and guides our daily actions. By analyzing the trajectory of a moving variable and its relative distance to the surrounding environment, the human brain recognizes the relationship between different viewing elements, their dimensions and depths, and our relative spatial position [41]. Furthermore, the speed of moving stimuli influences our perception of time. Ref. [50] conducted a series of five experiments to investigate how changes in variables such as the number of stimulus figures and their respective movement duration and speed influence subjective time perception. This study, which involved 59 participants, revealed that moving stimuli were generally perceived to have a longer duration than stationary stimuli, and higher speeds were associated with a greater extension of perceived time compared to slower speeds. Interestingly, the number of stimuli had minimal impact on time judgments. These results underline the significance of stimulus motion as a temporal cue, which support existing theories that define our experience of time as a psychological construct shaped by changes in perceived stimuli.

Similarly, a study performed by Ref. [51] tested the influence of movement on subjective duration through an experiment in which participants were exposed to rotating or translating shapes moving at a constant speed, accelerating motion, or decelerating motion. The responses from the 60 participants revealed that people tend to perceive scenes containing objects moving at a constant speed to last longer than those that are decelerating and interpret scenes with an accelerating shape to last the longest in duration [51]. The findings from this study highlight the importance of understanding specific characteristics of motion perception beyond just the speed of movement as explored by Ref. [50] by also including changes in velocity, as it can cause meaningful differences in our environmental perception. Further support for these findings comes from the studies conducted by [52] and [53]; which focused on time perception in slow-motion videos. Their research demonstrated that slow-motion videos could lead to an overestimation of duration, but this effect can be mitigated by informing participants about the actual playback speed. Additionally, providing information about the movement speed enhanced the perceived intentionality of displayed actions, highlighting the influence of such knowledge on cognitive evaluation processes. These studies contribute to our understanding of how motion perception impacts our perception of time and the evaluation of visual stimuli.

Table 2
Summary table of studies from the field of environmental psychology, which provide useful insights into the perception of movement.

Publication	Relation to view dynamism	Insights
[50]	Influence of movement speed on time perception	Participants evaluated the perceived durations of various geometric forms in five experiments, with results indicating that faster moving stimuli notably extended perceived time, whereas the quantity of stimuli had minimal influence.
[51]	Influence of movement speed on time perception	Speed of moving stimuli influences participants' subjective judgments on duration, which provides a valuable insight on the relationship between our attention and temporal information processing.
[52]	Influence of movement speed on time perception	Showed that slow-motion videos can cause an overestimation of duration, which is mitigated when participants are informed about the actual playback speed, demonstrating the impact of such knowledge on cognitive evaluation processes.
[53]	Influence of movement speed on time perception	Suggested that disclosing information about the degree to which a video is slowed down reduces the overestimation of duration, while concurrently enhancing the perceived intentionality of displayed actions.
[54]	Sensitivity to human movements	In three different experiments with an increasingly higher degree of abstraction of human movements presented as point-light displays, all participants were able to correctly identify walking movements from humans.
[55]	Sensitivity to human movements	Participants' ability to discern walking motion are significantly slow when the point-light sources are presented upside down but overall the identification ability remains robust despite the manipulation to the stimuli.
[56]	Sensitivity to human movements	Demonstrated robustness of human motion perception from point-light walker display by showing how it does not depend on low-level visual processing, such as being able to detect individual features or local relations
[57]	Sensitivity to human movements	Demonstrated flexibility of human motion perception by showing how introducing random dynamic noise through masking of the point-light display did not hinder participants' ability to identify walking movements.
[58]	Sensitivity to human movements	Participants can still correctly discern motion from other humans when they are presented using point-light displays combined with dynamic random noise composed of similar sized and colored dots.
[59]	Sensitivity to human movements	Participants were able to identify human movements from unrecognizable point-light display sources, proving to have a high sensitivity to human movements compared to other movement types.
[60]	Sensitivity to human movements	In testing participants' ability to discern a walking direction of human movement, the authors found that structural information in the display is essential for accurate identification.
[a] [61]	Categorization of movement based on agency	Defined action as movements of agents and introduced different views on actions with a focus on the Pluralist view, which defines agents' movements as activation of their abilities to move
[a] [62]	Differentiating agentive and non-agentive motions	Demonstrated the importance of differentiating agentive and non-agentive motions by examining the impact of action in language. Significant effects of performing agentive actions were found in participants' behaviors in sentence formulation and eye fixations.
[63]	Influence of motion on subjective impressions of the environments	The experimental results showed how motion and sound in the landscape influences perception of scenic beauty, which demonstrates the importance of including dynamic stimuli for research on environmental perception.
[64]	Effectiveness of video display for representing dynamic environments	Demonstrated how video representation can effectively simulate dynamic environments, capturing human interaction from multiple perspectives and conveying essential environmental aspects like sound and motion
[65]	Influence of display medium (photograph vs. video) on the preference of the environments	Participants favored landscape scenes presented in photographs over videos, with well-composed visuals consistently receiving higher ratings than poorly composed ones.
[66]	Importance of motion perception from evolutionary point of view	Introduced prospect-refuge theory - how humans prefer environments with a broad, unobstructed view (prospect) with a sense of safety or cover (refuge) - which can also relate to the importance of movement from an evolutionary perspective.
[67]	Importance of motion perception from evolutionary point of view	Introduced savanna hypothesis - how people prefer landscapes with open fields, water, and vegetation that offer a sense of protection and increased chance of survival - which can also relate to the importance of movement from an evolutionary perspective.

[a] We included these two studies from the fields of linguistics and philosophy, as the content of their findings closely relate to and support other papers reviewed in this section.

At the same time, we, as humans, have a remarkably high sensitivity to biological motions coming from other humans or other living organisms compared to movements generated by man-made or mechanical objects. In a study done by Ref. [54] involving 10 subjects, all participants were able to correctly identify walking movements from humans even though they were displayed in motion sequences using only point-light sources on discrete joints. The same result was reported when the author repeated the experiment a second time with increasing levels of stimuli abstractions, which further strengthened the conclusion of the first study. This finding was later confirmed by numerous other studies from the fields of behavioral and vision science, which continuously demonstrated the rapid and accurate recognition ability of human actions even from impoverished visual sources and/or when embedded in a noisy background [55,56,58–60,57]. In particular, in the study from Ref. [60] focused on the human ability to identify the direction of biological motions, the author conducted identification tests across four experiments differing in the amount of background noise and structural representation of the human body. The author found that structural information of human body representation was essential for people to accurately discriminate the walking direction, which leads to questions about which core features are necessary for identifying biological motion.

Studies using point-light displays have shown that humans can identify biological movement solely from localized motion signals from joints, which suggests that our perception of movement from animate subjects is not only rapid and accurate but also quite robust and flexible [60]. Our higher visual sensitivity to biological movements is thought to be evolutionarily advantageous, as humans live in inherently social environments [59]. Being able to accurately detect, perceive, and recognize biological movements is critical for surviving in a dynamic visual world [60]. Moreover, our actions can be defined by our agency and capacity to initiate and execute movement [61]. Therefore, we can distinguish agentive movements, resulting from the agents' capabilities, from non-agentive movements that are not triggered by the agents [61]. The ability to engage as an active agent and perform physical motions makes us especially sensitive to human movements, as the movements directly relate to how we interact with the physical world [62].

Evolution-based theories such as the savanna hypothesis [67] and prospect-refuge theory [66] suggest that our environmental sensitivity and preference come from adaptive responses based on survival and reproductive success [68]. According to those theories, people prefer views that often contain savannah-like landscapes, such as open fields, water, and vegetation, as they offer a sense of protection and a higher chance of survival [68]. Similarly, from an evolutionary perspective, our attentiveness to movements, especially towards biological movements, has a direct contribution to information about safety and resources, such as identification of a potential threat, awareness of changing weather conditions, and search for a warm protective shelter. Indeed, a study done by Ref. [63] demonstrates how our perception of landscape and subjective judgments of its scenic beauty gets influenced by the presence of motion and sound. In their study, comparisons on scenic beauty reported by participants were performed depending on whether landscapes were presented as static photographs or as dynamic videos with or without sound. The results showed that both motion and sound greatly influenced the participants' perception of scenic beauty. Reinforcing these findings, a study by Ref. [64] demonstrated the effectiveness of video representations in capturing dynamic environments like waterscapes. By incorporating essential environmental information, such as motion and sound, and offering continuous multi-views, video representations were found to be more comprehensive than static photographs. These insights illustrate how the inclusion of movement and auditory information can be critical for future research on environmental perception. However, Ref. [65] conducted a study with different image content and composition, which yielded an opposing outcome. Their research found that participants favored static photographs over video representations when judging scenic beauty of landscapes. This discrepancy in findings might be due to Ref. [65] excluding sound in their video representations and their study's focus on open agricultural landscapes, which are typically more still in nature compared to dynamic environments like waterscapes. These findings underscore the significant impact of presentation methods on preference ratings and call for careful consideration of these factors in environmental research to avoid oversimplified or erroneous conclusions.

In summary, our review of the studies from environmental psychology suggests that the type, speed, and context of movement are important considerations in understanding human motion perception. Ranging from simple shapes and point-light displays to landscape features, different visual stimuli have been utilized to uncover underlying mechanisms behind movement recognition and perceptual biases. Findings further disclose potential connections between our high sensitivity to biological motions and evolutionary biology, suggesting that our perceptual abilities may have evolved from survival strategies. Thus, integrating movement into view-out research, as shown in these studies, could effectively utilize insights from environmental psychology, thereby enhancing our understanding of view preferences.

3.3. *Dynamism in building science*

The focus of this section is on the dynamism observed in the view-out of a window, specifically excluding the broader scope of dynamism in mechanical systems and shading controls. In the field of building science research, it is essential to acknowledge the dynamic changes that occur in the built environment. These changes range from the moving shadows caused by changing daylight conditions to the evolving view-out of a window over time. The objective of this section is to expand our understanding of dynamism in view content within the broader context of architecture.

Views-out through windows provide a critical element of dynamism in shaping occupants' experience and interaction with the built environment. A recent comprehensive literature review conducted by Ref. [33] provided valuable insights into current understanding and findings on dynamic contents of window views. Similarly, Ref. [69] highlighted the significance of dynamism in window views and identified research gaps and opportunities for future investigations in this field. One of the key areas for further research is to determine the desired balance of movement in views that can offer non-distracting moments of interest [69]. Hence, this section aims to explore previous studies that specifically examined the effects of dynamism in view content, with the goal of establishing the current state of understanding.

A number of researchers have emphasized the importance of considering contextual influences of outdoor views, particularly in terms of temporal factors and dynamic movements, when assessing overall view quality [68,70,71]. Therefore, when conducting research on view-out perception, it is crucial to preserve the dynamic elements of a view through the chosen representation medium. This ensures that there is sufficient sensory information for making valid comparisons and predictions of experimental responses to the actual environment. In other words, an accurate interpretation of the viewing environment requires a dynamic representation of dynamic environments [63].

Studies of the visual appearance of indoor environments, including view-out conditions, mainly rely on two types of representations: 3D reproductions, such as 1:1 mock-ups in real physical spaces, or through the use of reduced-scale models, and 2D image reproductions, such as photographs, movies, or virtual renderings projected on digital screens or VR headsets [72]. To account for the advantages and disadvantages offered by these different representation mediums, we categorized the reviewed studies that directly investigated dynamic variables in view content based on how views were represented in their experiments. Out of the 18 studies included in this section, eight were conducted in real spaces (Section 3.3.1), seven with image projections on screens (Section 3.3.2), and one with simulations in VR environments (Section 3.3.3). Table 3 details 16 studies included in this section, categorized by their

Table 3
Summary table of view-out studies conducted on human subjects that directly investigated dynamism in view content using different representation mediums.

Publication	Represent-ation medium	Type of stimuli	Exposure time	Sample size	Dynamic stimuli	Dynamic variables studied	Outcome
[11]	Real windows	Views from participant's own workplace	N/A	333	Yes	Seasonal changes	Participants reported experiencing moderate to great differences between winter and other seasons
[73]	None (Real space with no windows)	Implicit association with nature	N/A	220	Yes	Seasonal & weather changes	Reported feelings of connectedness to nature and to the built environment differ based on seasons.
[74]	Real windows	Views from participant's own workplace	N/A	103	Yes	Nearby cars or traffic	Perceived view quality was reduced when nearby cars or traffic were present
[23]	Real windows	Views from participant's own workplace	N/A	106	Yes	Sky conditions	Whether the view has a clear sky or is partly cloudy influences its perceived quality.
[17]	Real windows	Views from participant's own workplace	N/A	30	Yes	Seasonality	A seasonal variation was found in reported affective states
[75]	Real windows	Views from participant's own houses	N/A	42	Yes	Movement	Dynamic and changing contents of views-out offer ways to interact with the outside world through storytelling
[76]	Real windows	Views from participant's own houses	N/A	20	Yes	Movement	Variability in exposure to dynamic external elements is important for residents
[24]	Real windows	Window views from the test room	10 mis	169	Yes	Sky types	Different weather conditions and amount of daylight influence view satisfaction
[8]	Computer screen	Photos of outdoor environments	~45 s per picture	20	No, static images	Brightness & weather types	A clear preference for sunny and bright views was found
[32]	Computer screen	Photos of views	N/A	484	No, static images	Nearby cars or traffic	Slight variance on view quality was found between participants' answers and D&V rating
[70]	16" laptop monitor screen	Pictures of nature views	15 s per picture	116	No, static images	Seasonality	Benefits of contact with nature do not depend on seasons
[31]	20" calibrated CRT monitor (1024 * 768 pixels for each image)	Pictures of real views from urban environment	15 s per picture	32	No, static images	Dynamic object type (people)	Participants preferred the presence of people in window views
[77]	Monitor screen (366 * 244 pixels for each image)	Images of window views in different window designs	N/A	181	No, static images	Dynamic object type (people and vehicles)	Presence of dynamic object type influences prediction of the perceived view quality
[78]	60" LCD screen (1 m viewing distance)	Static photos of window views	N/A	445	No, static images	Cloud level	Cloud level of 3 (30–60%) has the best view rating compared to other levels
[79]	65"OLED screen (2250 * 1384 pixels for each image)	Static photos taken from urban environment	15 s per picture	43	No, static images	Sky types and dynamic motifs (sidewalks or roads)	Participants rated sunny views to be higher quality than sunless views.
[80]	VR headset	Physically- based 360° panorama videos of timelapses	40 s per video	48	Yes	Lightness changes in views in different view types	Presence of luminous changes increases view-out quality and preference in dull scenes

representation types (literature review and statement articles were excluded from the table).

3.3.1. Dynamism in view content studied from real environments

The majority of studies reviewed in this section focus on examining the influence of daylight and meteorological conditions on view quality assessment in real environments across different times of day or seasons. Conducting experiments in a real environment has obvious advantages over using displayed or projected images on screens or VR headsets, as the dynamism of both view content and daylight are represented with real visual depth and lighting conditions [33]. However, due to the limitations on environmental control, experiments in physical space reduce the number of views and environmental variations for view representation.

Five out of the eight reviewed studies conducted in real environments have shown how our view appraisal is mediated by weather conditions and seasonal changes. Ref. [23] visited 106 employees and students from the NTNU campus in Norway over a 6-months period and asked them to evaluate the quality of window views from their respective sitting positions at their workplaces. The survey results showed that whether participants were interviewed on a clear or overcast day did influence their assessment of the view quality. However, as the study was conducted in an interview format at each participant's office with no ability to control environmental conditions or monitor personal variables, it is challenging to apply its results to other circumstances. Similarly, a study from Ref. [24] also showed that different weather conditions and the resulting variable amount of daylight in Poland influenced participants' view satisfaction. Although this trend was observed, the main objective of Wackzynska's study was actually to confront the participants' subjective assessments of view quality to the computational evaluation according to EN 17037 standard. Hence, the author mainly focused on horizontal sight angle, number of visible layers, and outside distance of view and did not conduct a detailed analysis of how changes in weather and daylight influence participants' view satisfaction.

In the Netherlands, Ref. [11] surveyed office workers at their workplaces, which included a question on seasonality and whether participants experienced differences in their view impressions as well as in their general mood and energy levels between summer and winter. A subset of the participants indicated having moderate to high differences in their moods between the dark winter season and the light season (rest of the year). A study by Ref. [17] on Swedish office workers also found a similar seasonal variation in the participants' self-reported affective states. However, both studies from Refs. [11,17] did not further investigate the impact of seasons on participants' perceptual impressions and left seasonality as a topic for further research. Using a rather different approach, Ref. [73] conducted experiments in a windowless test room in the United States and asked participants to perform the implicit task for their connections with nature. Their study demonstrated that participants felt a higher connectedness to nature during the mild autumn and spring months and a higher connectedness to the built environment during the winter months. However, their results were not replicated using explicit window view stimuli and require further studies for validation involving a systematic approach and a wide range of weather types and view contexts.

In addition to the studies mentioned above that primarily focused on daylight, meteorological conditions, and seasonality, recent research has started to highlight the role of changing external elements visible through windows in shaping occupants' experience and interaction with the built environment. A field study conducted by Ref. [76] revealed that occupants tend to favor window views that feature external elements that continuously move and change over time. Such views offer a sense of engagement and valuable information about the outdoor environment, thereby enhancing the perceived view quality. Similarly, a separate interview-based study conducted by Ref. [75] underscored the importance of window views for elderly subjects with limited mobility, who primarily reside at home. Out of the 42 subjects interviewed, many indicated that movements and changes in window views hold an even greater significance for them. They found these dynamics introduce elements of mystery, intrigue, and human interaction, further emphasizing the importance of dynamic view content for individuals with limited mobility [75]. The findings of these studies provide another angle of how occupants interact with the built environment and the importance of window views in shaping that interaction. However, the results of these investigations should also be considered with caution due to the limitations of the study design. For instance, in [75], although the elderly subjects provided valuable insight into the role of window views, it is important to note that this demographic may have specific needs and experiences that do not generalize to all occupants. Nonetheless, these studies underscore the potential importance of dynamic window views in enhancing occupants' experience and interaction with the built environment, presenting a promising area for further research.

Lastly, Ref. [74] conducted a questionnaire study in the Netherlands at the participants' workplace and surveyed their satisfaction with the outside view and daylight conditions. One of the view content variables investigated in the study was the presence of nearby cars or traffic, which reduced view quality in participants' subjective assessments. This finding later influenced the author to develop Daylight and View (D&V) analysis framework to assess view quality, which is analyzed in further detail in Section 4.1 of this paper. The survey results from this study, however, were not cross-validated or reproduced in future studies, which limits the conclusiveness of the author's finding as well as the D&V analysis method.

Experiments in physical space retain dynamism in viewing content using real window views. Eight studies reviewed in this section explored the impact of view dynamism through seasonal and meteorological changes as well as the presence of nearby cars or traffic. However, for three studies, dynamism in view content was not the main focus of the research, and therefore results were not confirmed through additional analysis. For the other five studies, environmental settings and experimental methods widely varied with no replication or cross-validation, thus restricting the generalizability and applicability of their research. In summary, the current findings from real window views show that temporal changes in daylight and weather conditions as well as the presence of movement, such as cars or traffic, affect building occupants' perceived view quality. The integration of these new research directions into existing knowledge, however, calls for a more dedicated focus on dynamism in view content and the validation of research methods in varied environmental settings. Further research is needed to consolidate our understanding of how occupants perceive and interact with the dynamic nature of their visual environment.

3.3.2. Dynamism in view content studied through image projections on screens

For research involving daylight, employing a digital projection has certain advantages over physical space by offering more control over different environmental factors, easier setup and reproduction of the results with a wide range of visual stimuli, flexible apparatus allocation without specific spatial requirements, and higher consistency in experimental conditions [81]. However, compared to experiments conducted in real spaces, image projections on screens have limited spatial depth, sense of presence, and ecological validity. Furthermore, despite our continuous effort to search for studies using dynamic stimuli on digital projections, all reviewed literature uses static stimuli of photographs with no inclusion of movements or temporal changes in views-out.

One study by Ref. [70] examined the impact of seasonal changes using the static image projection method on a monitor screen. They found that nature-related mood effects do not depend on seasonal conditions, and contact with nature improves participants' affective states throughout the year. Two of the other reviewed studies using the same representation method focused on changing weather conditions [8]. showed 36 randomly selected static images of natural and built environments to 20 students from the Eindhoven University of Technology and asked them to rate their subjective impressions. Their study found a clear preference towards brighter environments with sunny skies compared to darker environments with overcast skies. Similarly, Ref. [79] presented 15 window views taken from urban environments in both sunny and cloudy weather conditions to 43 participants and compared their subjective view ratings in 5-point Likert scale. The authors also measured participants' brain waves during the view observation period using wearable electroencephalography (EEG) devices. It was found that participants rated view quality to be significantly higher under sunny conditions and also reported the highest physiologically positive responses characterized by lower power of alpha waves in the left hemisphere. On the other hand, a study by Ref. [78] performed with a more direct focus on view-out contradicts their findings. In this study, 445 participants were asked to evaluate the view quality of randomly selected static images of window views from an urban area of Taipei, Taiwan. Their survey results indicated that views with a cloud percentage of 30–60% (cloud level 3) were preferred over clear skies with 0% cloud in the sky. The outcomes from these three studies, however, cannot be directly compared, as each study used unique visual stimuli collected in different environmental settings.

Alternatively, studies by Ref. [32], [31], [77] and [79] used static pictures of window views to investigate the influence of dynamic objects in the view content, such as people and traffic. In a study by [31], for instance, participants' preferences, verbal reasoning, and eye-tracking responses were examined using 40 photographs of urban views. The results revealed a clear preference for views featuring people, as evidenced by participants' desire to observe and gather more information about people's presence and activities. The gaze behavior analysis was also consistent with this finding, as there was a notable attraction towards human faces present in the scenes. However, generalizing these findings to real window views and diverse environments may be challenging, as the study exclusively utilized urban views, and each scene was only shown for a short duration of 15 s. The other studies did not have clear findings on the effect of this variable on the participants' perceived view quality. Ref. [32] found the presence of nearby cars or traffic to have an impact on the participants' view ratings, which could have been one of the difference factors between the participants' view ratings and the view quality scores from their D&V method. Similarly, Ref. [77] identified the presence of people and traffic presented in photographs as dynamic view parameters with an influence on the perceived view quality; yet, this variable was not the main focus of their study, and no separate analysis was done to investigate its specific influence. Lastly, Ref. [79] factored in pavements, footpaths, and roads as dynamic motifs associated with movement when assessing view quality. However, the authors did not conduct a separate assessment of these motifs' impact on perceived quality, as the primary objective of their study was to evaluate the accuracy of different view rating methods compared to their experimental results, with a particular emphasis on natural elements and weather conditions.

Similar to the previously reviewed studies conducted in physical environments, the seven studies included in this section examined dynamism in view content by focusing on moving objects and temporal changes in the sky and seasons. The use of a projection allowed more variations in environmental contexts and testing of a broader range of view scenes compared to real windows. However, all seven studies used static stimuli of images and photographs to represent views-out, and dynamic viewing elements were only implied in the captured conditions. Additionally, with a lack of focus and differing interests, our review did not encounter a clear finding or consensus among the studies.

3.3.3. Dynamism in view content studied in VR environments

Virtual environments have significantly advanced studies on lighting perception and view-out, especially with the ability to provide three-dimensional stereoscopic vision, fully immersive depth perception, and 1:1 scale simulation [82]. However, modeling the VR scenes requires a thorough validation of light characteristics, such as luminance contrast and spectral intensity, due to its constrained luminance range. Hardware characteristics (i.e., headset luminance range, pixel density, and constraints on the field of view) may also pose additional challenges in model validation with a potential side effect of cybersickness, including headaches, eyestrain, nausea, and disorientation [82]. At the same time, similar to the reviewed studies using a digital projection method, most view-out studies conducted in VR utilize static stimuli of rendered images and photographs without incorporating movements or temporal changes within a view.

The one reviewed study by Rodriguez et al. conducted in VR environments represented views as 360° stereoscopic panoramas. This method of using 360-degree panoramas in VR has recently been proven to offer closest-to-reality results and physiological responses by ensuring a sense of presence for participants in their visual interaction with the represented spaces [83]. Ref. [80] focused on the influence of variations in daylight on our view perception using dynamic stimuli. Their findings showed that having luminous changes in a window view leads to higher view satisfaction from building occupants. Although their method captured the dynamic movement of daylight by using videos to visualize the views, they manipulated the speed of movement through a timelapse technology and sped up the videos by 30 times compared to the actual speed, which limited the generalizability of the authors' conclusions.

To summarize, despite technological advances in VR development, there is a lack of research in the dynamic representation of views-out. Our search found only one applicable study for review, which used timelapse to represent movement in views. Due to limited output, we could not provide conclusive findings from VR studies. Additionally, the effects of various factors on our perception of view - such as scale, duration, and frequency of moving objects - remain unexplored and unknown. Thus, more studies are needed to develop an appropriate representation methodology to visualize dynamic views-out in VR and to investigate different aspects of movement in views.

4. Implications for the built environment

4.1. Dynamism and view rating metrics

Once we established how dynamism in views-out is currently being understood and researched, we wanted to inquire how dynamism gets evaluated in assessing view quality. In this section, we reviewed view rating metrics published to date that incorporate dynamism in their assessment. Our search revealed that view dynamism is absent in most of the widely used view assessment criteria, including the EN 17037 "Daylight for Buildings" European standard [84]. In total, only four metrics were found to include view dynamism (see Table 4).

The dynamic aspect of view content has been incorporated into a few sustainable building rating systems. For instance, in the LEED rating system, the view content parameter is described as "views that include at least two of the following - (a) flora, fauna, or sky, (b) movement, and (c) objects at least 7.5 m from the exterior of the glazing" [85]. Similarly, view content is described to be generally more attractive when it has "brighter areas with some movements" in the Green Star NZ rating system [86]. Dynamism in view content has been mentioned as one of the important design considerations by some of the leading building rating systems. However, their approach remains of little practical use, as the basis of the criteria applied in these rating systems is vague and what constitutes movement in their definition and how its criterion can be fulfilled is unclear.

Furthermore, several authors have developed indexes for assessing the quality of a window view concerning dynamic view content or have the potential to include dynamism as a relevant factor [74]. was the first to propose a view quality score using the D&V analysis method, which considered the assessment of both the daylight and view quality of windows. Their method evaluated daylight quality by first making an equidistant projection of a window view and then studying its luminance distribution, which has the potential to be further developed to include dynamic daylight and sky conditions over an extended period [32]. In assessing view quality, the authors developed a point system for a flowchart consisting of multiple-choice questions to derive the influence of different view content variables. The determinants consisted of the presence of nature, the number of visible layers, the presence of natural water or traffic, diversity, and the maintenance and features of the building(s). The view is then rated to be low if it has less than 4 points, medium for 5 to 7 points, or high quality for greater than 8 points in total.

The view quality determinants for the D&V method acknowledged dynamic movements in view content by including the presence of nearby cars or traffic; however, the flowchart remained at a developmental level using a subjective rating method that was not validated. The determinants were chosen based on the existing studies on view content and subjective preference as well as the author's own findings

Table 4
Summary table of four view rating metrics that incorporate view dynamism in their view quality assessment criteria.

Rating System	Rating Method	Dynamism Parameter	Dynamism Assessment
D&V analysis [74]	Daylight quality through equidistant projections and view quality through a point system for a flowchart consisting of multiple-choice questions on view content variables	Presence of nearby cars or traffic	Nearby cars or traffic in views deducts a point in view rating
LEED [85]	A list of requirements for fulfilling sustainable building rating	Movement in view content	Movement in views is listed as one of the three required parameters for fulfilling the rating
Green Star NZ [86]	A list of requirements for fulfilling sustainable building rating	Brighter areas with some movements	View content is described to be more attractive
VQI Index [18]	View quality calculated through a multiplication of view content, access, and clarity variables	Presence of movement and its distance from the observer	Distant movement is favored while no movement or nearby movement reduces view quality

from a questionnaire study on office workers. Using the online questionnaire, the author surveyed 103 respondents from the faculty of architecture at the Delft University of Technology and inquired about their preference for outside views and lighting conditions in their workplace environments. The survey data indicated a lower preference towards views with nearby cars or traffic, which resulted in a point deduction in the view quality score flowchart. Although the D&V analysis influenced the development of other valuable view assessment metrics, the author's choice and orders of the view quality determinants as well as the point system in the flowchart relied on a single questionnaire study on a limited sample size, which questions the reliability of this method.

Most recently, Ref. [18] developed the VQI, which uses three variables - content, access, and clarity - to describe view quality. Each variable ranges from 0 to 1, and the final view quality evaluation integrates all three variables by multiplying the three corresponding values. Unlike other metrics, VQI incorporates dynamism directly into its equation for quantifying view-quality. In their approach, movement is only included as part of the ground layer view and benefits the view quality if it is not present or far from the observer with a distance greater than 6 m. While the 6 m distance as a determinant for the content distance was derived from the minimum exterior view distance specified in EN 17037, the authors did not provide clear justifications in their publications for the assigned weights (1 for distant movement, 0 for no movement, and 0.5 for nearby movement). Furthermore, the type, speed, scale, or interaction of the movement to its surrounding environmental context is not considered in the current equation. To conclude, most view rating metrics used by architects and researchers do not acknowledge the importance of dynamism in view content. Of the four reviewed metrics, the VQI is the only one that includes view dynamism in its equation. However, as movement is rewarded only when absent or far from the observer, we believe that this approach is highly limited and remains rudimentary. Hence, more experiments specifically focusing on view dynamism are necessary to define and justify specific extents and conditions in which movement can improve perceived view quality with justifications.

4.2. Discussion and recommendations

The present review highlights the need for an in-depth investigation of the intricacies inherent in dynamic movement and temporal changes in view content. The multidimensional interplay between human perception and the dynamic visual world, as revealed by vision science and environmental psychology research, underscores the critical importance of movement type, speed, and context in our perceptual processes. The multifaceted nature of motion detection systems, which interpret movement as patterns within three-dimensional spaces, is characterized by distinct sensitivities to both spatial and temporal frequencies. Additional complexities are introduced by the influential roles of contextual cues, low-level visual processing, contrast, and multisensory interactions in motion perceptions. These insights open a new avenue of exploration for view-out research, enhancing our understanding of human interaction with the dynamic visual world. Through the utilization of a broad spectrum of visual stimuli, ranging from simple shapes [50,51] to complex landscapes [63–65], researchers have shed light on the mechanisms behind movement recognition and perceptual biases. Additionally, these studies provide compelling evidence of a potential evolutionary linkage between our acute awareness of biological motion and our survival instincts. Despite these advancements, the practical application of these findings in the real world still faces certain constraints, thus underscoring the need for a comprehensive examination of the dynamism within view content. Although research suggests that variables such as alterations in daylight, weather conditions, and presence of movement, like traffic, may influence perceived view quality, these studies are somewhat superficial and restrictive. Investigations conducted in both physical and virtual environments have largely overlooked the crucial element of dynamism in view content, thereby limiting their applicability.

Our review thus calls for additional research to investigate the specific features and contexts of dynamic movement and temporal changes in view content that affect our perception. To achieve this, it is crucial to develop more advanced methodological tools that can effectively measure, categorize, and represent movement in viewing contents within an experimental setting. Moreover, the review underscores the urgent need for further validation studies on view assessment strategies to differentiate specific types and conditions of dynamism in views and clarify the extent of its impact on perceived view quality. In light of the findings of this review, we suggest the following recommendations for future research on dynamism in the context of the built environment (i.e. view-out of a window). It is important to note that our proposals are based on the current state-of-the-art and may evolve over time as new research and findings emerge.

Proposed guidelines and recommendations classified by topic and timeframe:

- Investigating the effects of specific movement features (short-term):
  - Incorporating knowledge from the vision science research by differentiating moving variables in view content with a high level of attentional saliency and behavioral urgency (i.e., sudden onsets, looming movement, introduction of new object)
  - Extending findings from the field of environmental psychology by conducting comparison studies on the perceived view quality when a view contains biological movement from humans and other forms of nature (i.e., pedestrians, birds, tree foliage) versus artificial movement from man-made inanimate objects (i.e., cars, trains, planes)
  - Examining the extent to which speed of movement influences view perception by comparing constant movement to those with changes in velocity (i.e., acceleration or deceleration)
  - Investigating whether the scale of movement influences view perception in different environmental contexts by comparing varying levels of movement in different environment types (i.e., relatively still open agricultural fields vs. highly active urban streets)
- Developing research methodologies (short-term):
  - Developing a more precise classification of the dynamic elements for studies on indoor and outdoor environments by incorporating literature from vision science, environmental psychology, and building science.
  - Replicating findings from previous studies in a variety of environmental contexts with a focus on dynamism in view content using real window views
  - Investigating the effect of incorporating real motion in view representation by comparing window views presented as static images to those presented as videos
  - Critically examining the effects of representation details for using video displays (i.e., including video speed information or auditory information) on view impressions
  - Developing a new representation methodology to represent dynamic window views on monitor screens or VR without using timelapse technology or manipulating movement speed
  - Systematically assessing perceived view quality through both direct subjective assessments (i.e., questionnaires and verbal reasoning) and indirect physiological measures (i.e., heart rate variability, electrodermal activity, brain waves) in studying view dynamism
- Incorporating dynamism in view rating metrics (long-term):
  - Differentiating desired levels of movement in window views depending on the type of buildings and occupant activities based on research findings
  - Adjusting the existing view indexes and design standards or making new metrics to appropriately represent view dynamism to

further enhance our current understanding of the importance of view-out and its quality assessment

5. Conclusion

In this review, we analyzed a total of 51 previous studies from the literature that either directly investigated dynamism in the content of the view-out or provided relevant insights on this topic. Most of the existing literature on view-out research tends to focus on the importance of high-quality window views and presenting view quality assessment methodologies and tools for data collection and view representation. The dynamism of viewing content has been mentioned by many researchers to be an important consideration for assessing view quality, yet there are only a few studies with a dedicated focus on dynamism in view. Given the spread of approaches, existing findings were often not comparable thereby highlighting the need for consensus on a unified definition of view dynamism and methodology to categorize different types, speeds, and scales of movement and temporal changes in views.

With this review, we would like to encourage scholars and researchers to continually explore and expand their knowledge in this field to develop more precise and accurate methods of representing and assessing dynamism in view content. Across all representation mediums, the focus should be on accurately capturing what the view towards the outside brings to our interior environments. The implications of future research on view dynamism include informing both academic current status quo and design communities about the extent to which movement matters in view appreciation. Through a more comprehensive understanding of view-out quality, the ultimate aim of our review is to lead research in directions that further enhance indoor comfort for building occupants by providing high-quality views to a broader community.

CRediT authorship contribution statement

Yunni Cho: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Caroline Karmann:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Marilyne Andersen:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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