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The mind meets the museum: A psychology-based design framework for enhancing museum experiences

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ABSTRACT

Museums represent one of the primary cultural attractions worldwide. Over the last decade, they have undergone a significant transformation in their societal role, driven by increasing recognition of their potential to promote psychophysiological well-being. This conceptual paper aims to: i) provide an integrative synthesis of current interdisciplinary theoretical and empirical literature on the psychological processes that both shape and are shaped by the museum experience; ii) propose a psychologically grounded design framework organized across four core dimensions (sensory-perceptual, emotional, cognitive, and motivational); and iii) offer practice-oriented considerations to support reflective and context-sensitive decision-making in the design of museum experiences and environments. Building on literature from psychology, neuroscience, and museum studies, the paper advances a cohesive theoretical framework that integrates these perspectives and provides a conceptual scaffold for exploring the psychological dimensions of the museum experience.

1. Introduction

Museums are cultural and educational institutions that offer unique opportunities for learning, engagement, and reflection [1–3]. In the past, they were traditionally perceived as repositories of art, history, and science, playing a key role in preserving and presenting the cultural heritage of societies [4].

In recent years, however, there has been a growing recognition of the potential of museums to contribute to visitors' wellbeing [5]. Contemporary museum experiences have evolved from static exhibitions to dynamic, participatory environments that engage visitors on cognitive, emotional, and social levels [6,7]. This shift is driven by an understanding that the museum experience is not just about viewing objects – despite their intrinsic value – but about enabling meaningful, memorable, and potentially transformative visits [8–10].

The potential of museums to enhance psycho-physiological well-being has emerged as a significant focus in recent interdisciplinary scholarship across psychological, neuroscientific, and museum studies literatures [5,11,12]. In fact, research has demonstrated that engagement with art and cultural heritage can activate multiple psychological mechanisms associated with stress reduction, affective modulation, and psychological resilience [13–15].

Research from the field of environmental psychology has shown that museums can function as restorative environments that reduce directed-attention fatigue and support reflective states through mechanisms such as fascination, spatial coherence, and psychological distance from everyday demands [16]. Neuroscientific and psychophysiological studies reveal the neural and bodily mechanisms through which aesthetic and cultural experiences modulate affective states, reduce stress markers, and promote cognitive engagement [17–19]. Furthermore, embodied cognition frameworks highlight how spatial design, object handling, and multisensory engagement shape visitor meaning-making, autobiographical memory activation, and learning consolidation [20–22].

However, beyond a limited number of pioneering institutions, a major challenge remains in the systematic integration of insights from psychology, neuroscience, and museum studies into a coherent framework capable of informing museum design and practice [1,7]. The lack of such integrative approaches limits the translation of theoretical and empirical advances into innovative strategies for enhancing visitor experience and wellbeing in cultural settings [11,23].

It is worth noting that psychologically informed design should not be

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equated with comfort optimisation. Museums may also ethically design for productive discomfort, critical reflection, and accountability.

The literature is first synthesised by identifying the most influential theoretical models and frameworks across neuroscience, psychology, and museum studies. Building on this synthesis, we propose an original framework organised around four psychological dimensions, sensory-perceptual, emotional, cognitive, and motivational, which together provide a structured and actionable lens for museum experience design.

The general objective of this paper is therefore twofold: (i) it consolidates dispersed interdisciplinary knowledge into a coherent conceptual map of how museum environments influence visitor experience and wellbeing; and (ii) it advances a theoretically grounded yet practice-oriented framework that can guide inclusive and supportive museum design. The framework is not intended as a prescriptive model, but as a flexible scaffold adaptable to diverse institutional contexts, visitor populations, and curatorial goals.

2. Literature synthesis: the psychological dimensions of the visitor experience

Understanding how museums shape visitor experience requires looking beyond disciplinary boundaries. This section therefore draws together key insights from psychology, neuroscience, and museum studies to illuminate the psychological processes that unfold during a visit. Rather than offering an exhaustive review, it selectively engages with the most influential theoretical models and empirically grounded contributions that speak directly to design. The literature considered here emerges from structured searches across PsycINFO, Web of Science, and Google Scholar, with priority given to foundational frameworks and peer-reviewed studies from the past three decades that clarify how museum environments influence perception, emotion, cognition, and motivation. Literature was selected based on three criteria: (i) conceptual influence within museum studies, environmental psychology, neuroscience, or visitor research — prioritising foundational theoretical models; (ii) empirical grounding in experimental studies, intervention research, or systematic visitor observation demonstrating psychological mechanisms operative in cultural contexts; and (iii) direct applicability to museum experience design, meaning findings that can inform spatial, curatorial, technological, or interpretive decisions.

Four converging theoretical traditions grounded in museum research across different disciplines inform the four-dimensional framework proposed in Section 3. Each tradition contributes distinct theoretical resources, and their convergence — as will be argued at the close of this section — reveals a shared underlying structure that motivates the analytical proposal advanced here.

A first cornerstone is the restorative museum line of work, which explicitly applies environmental psychology to museum contexts. Attention Restoration Theory (ART), originally formulated by Kaplan and Kaplan [11,24], conceptualises restorative environments through four interacting constructs: being away, extent, fascination, and compatibility. Subsequent visitor research operationalised and extended this framework to museum settings, demonstrating that museums and galleries can be perceived as restorative environments and identifying key experiential moderators, including opportunities for reflection, physical comfort, environmental legibility, and control over contextual factors such as crowding and room temperature [16,25,26]. Crucially, however, this body of evidence relies predominantly on self-reported perceptions rather than direct physiological or cognitive performance measures [23], indicating that restoration in museums is not an inherent property of the environment but an emergent outcome that depends on specific design and visitor conditions. More recent studies have further refined this picture by showing that perceived visit duration and cognitive load modulate restorativeness: museums appear to function as restorative environments primarily when pacing, sequencing, and environmental demands remain within manageable thresholds [27]. This suggests that restoration is best understood as a design-dependent outcome, achievable through deliberate curatorial and spatial decisions rather than guaranteed by institutional type alone.

A second museum-specific tradition is the object-based wellbeing or heritage-in-health framework, which positions the museum encounter — particularly tactile object handling — as a mechanism integrating sensory engagement, meaning-making, autobiographical memory, and social connection. Chatterjee and colleagues argued, and empirically tested, that museums and galleries can function as partners in public health by offering modes of engagement that support wellbeing outcomes extending beyond conventional learning metrics [5,12,28]. Intervention studies involving structured object-handling programmes with older adults, hospital patients, and mental health service users report improvements in outcomes including social connectedness, affective activation, cognitive stimulation, and sense of purpose. However, as these findings derive predominantly from facilitated programmes with specific participant groups, their generalisability to everyday, unstructured museum visitation remains limited. Object-based wellbeing effects should therefore be understood as context-dependent and mediation-sensitive rather than universally elicited, with important implications for how such mechanisms might be embedded within broader design strategies [23].

A third pillar derives from visitor experience frameworks developed within museum research that, while not formulated explicitly in wellbeing terms, offer robust accounts of how museum encounters generate personally meaningful outcomes [2]. Falk and Dierking's Contextual Model of Learning conceptualises museum experience as emerging from the dynamic interaction of personal, sociocultural, and physical contexts [20], foregrounding visitor agency and contextual variability as central determinants of experiential outcomes. The theoretical significance of this framework for the present synthesis lies not in its explicit treatment of wellbeing — which it does not provide — but in its explanatory account of how the conditions that plausibly support wellbeing are produced and sustained within free-choice museum environments [24,26]. It thus provides a structural basis for understanding how design can create the contextual conditions under which psychological processes of interest become operative.

A fourth pillar engages with museum-specific measurement and outcome frameworks, included here not as a theoretical source for the framework itself, but as a necessary methodological complement to the preceding traditions [29,30]. Claims regarding wellbeing impact require empirically tractable outcome structures, and existing evaluative frameworks offer partial but important resources in this regard. At an institutional level, the Generic Learning Outcomes (GLO) framework [138] provides a structured approach for evidencing affective, social, and attitudinal change alongside cognitive outcomes, enabling museums to move beyond attendance metrics toward articulated experiential impacts. Nevertheless, current evaluative approaches remain fragmented, and the relationship between measured outcomes and underlying psychological mechanisms is often implicit rather than theoretically specified. This gap, between what can be observed and measured and what can be explained, motivates the need for a framework that makes psychological mechanisms explicit and thereby renders them available for intentional design.

Taken together, these traditions converge on a central insight: museum experiences arise from the dynamic interplay of sensory-perceptual, emotional, cognitive, and motivational processes, and any wellbeing effects depend on design, context, and modes of engagement rather than being inherent to museum visitation itself. Although each tradition foregrounds different mechanisms, their convergence reveals a shared underlying architecture in which these processes interact to generate outcomes of personal and social significance. The four-dimensional framework proposed in the following section builds on this convergence by articulating a structure already implicit in the literature. Its dimensions (i.e., sensory-perceptual, emotional, cognitive, and motivational) capture the distinct yet interdependent psychological processes that recur across environmental psychology, neuroscience,

and museum studies.

3. From literature to framework: the psychological dimensions of the visitor experience

Building on the mechanisms identified in Section 2, this section introduces an original integrative framework organized around four psychological dimensions: sensory–perceptual, emotional, cognitive, and motivational. These dimensions are not conceived as isolated constructs, nor do they represent the only possible way to organise the evidence surveyed above (see Fig. 1). Rather, their selection and organisation reflect the authors' analytical reading of four converging theoretical traditions, each of which foregrounds a partially overlapping but distinct cluster of psychological processes. The claim advanced here is that these four dimensions constitute a theoretically motivated and empirically grounded structure for making sense of how visitors experience museums — and for translating that understanding into actionable design implications. The framework is integrative in that it draws on empirical findings from neuroscience, environmental psychology, and museum studies, and operational in that it articulates how each dimension can be intentionally engaged through environmental, spatial, curatorial, and technological design strategies. Within each dimension, empirical evidence is synthesised to clarify the psychological mechanisms at stake, and this synthesis is then extended by identifying the design strategies through which those mechanisms can be intentionally leveraged. The framework thus serves a dual function: it provides a theoretically grounded account of how visitors experience museums psychologically, and it translates that account into a coherent and actionable structure for museum experience design.

3.1. The sensory-perceptual dimension

The sensory-perceptual dimension of the museum experience focuses on how external stimuli are received and interpreted by our senses [31,32]. By strategically varying the intensity and nature of sensory stimuli, museums can actively shape visitor attention and engagement, mitigate museum fatigue [27], and enhance the depth of the experience itself [33]. This approach necessitates considering the perceptual clarity of the exhibits, the seamlessness of the visitor experience, and the strategic design of both the exhibit setup and the environment [34]. Three interconnected aspects define this dimension: the interpretive competencies through which visitors make sense of what they perceive, the behavioural patterns that characterise how perception unfolds across a visit, and the spatial, individual, and technological factors that shape the perceptual environment itself. Each of these aspects has distinct design implications, and together they constitute a comprehensive account of how sensory-perceptual experience is produced and sustained in museum contexts.

3.1.1. Visual literacy and the transition from perception to meaning

A first critical yet often overlooked aspect of the sensory-perceptual dimension in museums is the process of translating visual experiences of exhibits into verbal articulation. Since the 1980s, visual literacy — the ability to decode and understand images [35] — has been introduced in the museum context, indicating the ability to comprehend and make use of works of art [36]. Teaching visitors to observe should help them transition from purely subjective judgements, influenced by aesthetic preferences and prior experiences, to a broader and more reflective perspective when interpreting museum objects. To accomplish the transition from visual to verbal communication, museums may implement strategies such as guided discussions, interactive labelling, and digital storytelling tools [37].

Techniques like Visual Thinking Strategies (VTS) have demonstrated success in fostering critical observation and encouraging verbal articulation of visual content [36]. Such techniques consist of asking open-ended questions about images or artworks, prompting viewers to describe what they see, interpret meaning, and justify their observations with evidence [36,38]. Additionally, integrating multimodal resources — such as text panels, audio guides, and interactive exhibits — can further enhance perceptual and cognitive engagement [39]. Visual literacy development is not, however, a uniform process: visitors differ substantially in their prior exposure to art, their familiarity with museum conventions, and their confidence in articulating perceptual responses. Design strategies that support the development of visual

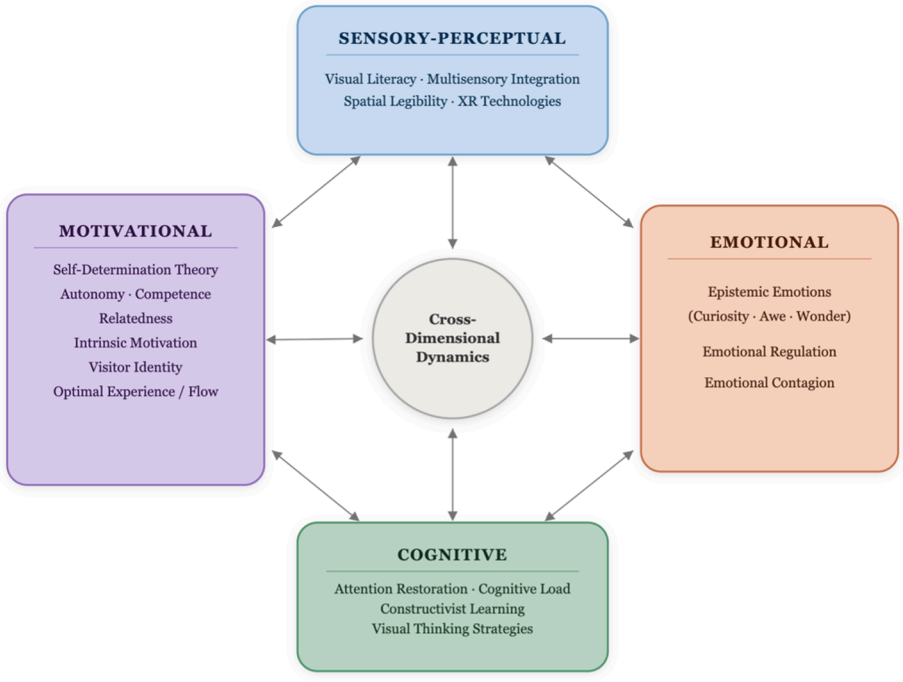

Fig. 1. Conceptual framework of cross-dimensional dynamics in visitor experience. The diagram depicts the reciprocal interactions among the sensory–perceptual, cognitive, emotional, and motivational dimensions, emphasizing their bidirectional influences. The central node represents cross-dimensional dynamics, referring to the integrative mechanisms through which factors such as visual literacy, multisensory integration, cognitive load, emotion regulation, and intrinsic motivation jointly shape experience quality, learning processes, and flow states. The framework highlights the systemic, interdependent nature of visitor experience, particularly relevant to cultural contexts and technology-mediated environments (e.g., XR).

literacy must therefore accommodate a wide range of starting points, offering scaffolded entry points that neither presuppose expertise nor condescend to those who possess it.

3.1.2. Patterns of sensory-perceptual flow in museum visits

A second critical aspect of the sensory-perceptual dimension concerns how visitors move through and perceive the exhibition environment as a whole. Mazzolini [33], drawing on earlier research [40], identified several recurring patterns in how visitors engage with museum spaces from a perceptual standpoint. At the outset of a visit, individuals typically explore the exhibition space to gain an overall impression, rather than focusing immediately on specific objects. Within the first 30 minutes, attention levels are at their peak; however, this focus tends to wane as time progresses [27,33]. Moreover, the time devoted to each exhibit is often proportional to the perceived length of the entire visit — shorter in large exhibitions — and decreases noticeably as fatigue sets in Ref. [41]. When presented with a directional choice, visitors show a marked preference for turning right, favouring displays located on that side.

These tendencies are reinforced by crowd dynamics and imitation behaviours. As the end of the visit approaches, the mere sight of the exit exerts a psychological pull, dramatically reducing attention devoted to nearby displays [32,33]. Similarly, interaction with explanatory materials such as labels or captions shows a polarised pattern: while some visitors thoroughly read them, many simply skim or skip them entirely [29]. Beyond movement, spatial orientation plays a crucial role. Visitors rely on perceptual cues — visual or environmental — to navigate and make sense of exhibitions [2,21]. Clear signage and intuitive spatial organisation help reduce cognitive load, allowing visitors to focus on content rather than layout [25,26]. Bitgood further notes that visitor behaviour results from interactions between prior experiences, cognitive styles, and exhibition design, while Antinucci emphasises how overcrowding can negatively impact perception and memory [42]. These behavioural patterns are not merely descriptive findings but design-relevant constraints: understanding how perception naturally unfolds across a visit allows curators and designers to structure exhibitions in ways that work with, rather than against, the natural arc of visitor attention.

3.1.3. Space, sensory variability, and perceptual mediation

The third aspect of the sensory-perceptual dimension concerns the factors that actively shape the perceptual environment — and hence the conditions under which the patterns described above play out. These factors operate at three interconnected levels: the organisation of physical space, the variability in how individual visitors process sensory information, and the technologies that extend or mediate perceptual engagement. Understanding how these levels interact is essential for designing environments that are both experientially rich and genuinely inclusive.

At the first level, the relationship between architectural organisation and perceptual engagement has been systematically examined in museum research. Tzortzi's analysis of visitor movement demonstrates that spatial layout directly shapes patterns of exploration and attention: open gallery configurations tend to encourage free-ranging movement and self-directed discovery, while segmented or linear arrangements guide visitors along predetermined sequences, influencing both the depth and order of engagement with individual exhibits [43]. Beyond circulation patterns, spatial hierarchies — including focal points, thresholds, and visual axes — modulate visual attention and wayfinding, shaping the interpretive experience before any direct object encounter occurs. Spatial organisation thus functions as a perceptual framework that structures what visitors notice, how they move, and how meaning is assembled across a visit. This spatial dimension extends naturally into the multisensory register: museums are not only visual environments, and the relative salience of each sensory channel — sight, hearing, touch, smell, kinaesthesia — is itself a design variable [44,45]. The strategic use of non-visual sensory modalities can significantly deepen engagement: tactile elements invite direct physical contact with material qualities that vision alone cannot convey, while olfactory cues can activate autobiographical memory and emotional response in ways that visual stimuli rarely achieve [46,47]. Decisions about which sensory channels to engage should be guided not only by the experiential qualities they afford, but by their contribution to the interpretive purpose of the exhibition — sensory enrichment that does not serve meaning-making risks becoming distraction rather than enhancement.

At the second level, the profound variability in how individual visitors process sensory information has direct implications for inclusive design. Sensory conditions that are comfortable or stimulating for one visitor may be overwhelming or insufficient for another, a variability that is particularly marked among neurodiverse visitors. Individuals with sensory hyperreactivity — common in autism spectrum conditions, ADHD, and related profiles — may experience bright lighting, ambient noise, or dense visual environments as acutely distressing rather than engaging [48]. Conversely, those with sensory hyporeactivity may seek more intense stimulation to achieve adequate perceptual engagement. Inclusive sensory design must therefore move beyond the accommodation of named disabilities toward a broader recognition of human perceptual variability. Practically, this implies providing sensory regulation zones — quiet, low-stimulation spaces with soft lighting and minimal sound — alongside designated higher-stimulation interactive areas and offering clear advance communication about the sensory characteristics of exhibitions, including noise levels, lighting intensity, and the availability of quieter spaces, to enable visitors to self-regulate and plan accordingly [49]. These provisions benefit all visitors: sensory fatigue is universal, and offering meaningful choice in sensory engagement modes enhances experience quality across the full range of the visiting public, not only for those with identified needs.

At the third level, Extended Reality (XR) — encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) — introduces new perceptual possibilities while also generating new forms of sensory demand that intersect directly with the individual variability described above. VR enables fully immersive environments in which sensory parameters can be precisely controlled, making possible encounters — such as inhabiting historical spaces or navigating microscopic structures — that no physical environment could provide [50]. AR overlays digital information onto physical objects and spaces, revealing hidden layers such as X-ray views of paintings or reconstructions of fragmentary artefacts, while preserving the visitor's connection to authentic material culture [51]. In this respect, XR extends rather than replaces the perceptual encounter with objects, offering new registers of engagement that can deepen rather than substitute for direct experience. Yet the same perceptual intensity that makes XR powerful also makes it a source of significant risk: VR can induce cybersickness through conflict between visual motion cues and vestibular feedback [52], and the dense sensory complexity of immersive environments can exceed the processing capacity of visitors with sensory sensitivities, making intense XR experiences potentially distressing for neurodiverse visitors in ways that are difficult to anticipate without prior disclosure of the sensory demands involved [48]. Additionally, the perceptual richness of XR can redirect visitor attention away from physical objects, with visitors engaged in headset experiences potentially bypassing the artefacts around which museums have historically organised epistemic authority: an authority now increasingly shared, challenged, and negotiated with communities and scholars [53]. These risks are not arguments against XR deployment, but they are arguments for its principled design: adjustable sensory parameters should be standard rather than exceptional, clear communication about sensory demands should precede the experience, non-XR alternatives should always be available, and digital mediation should in each case be guided by a clear interpretive rationale ensuring it functions to deepen engagement with material culture rather than to displace it.

3.2. The emotional dimension

Emotions play a fundamental role in shaping the initial encounter with museum objects. They can support and reinforce perceptual, cognitive and motivational processes activated during object viewing, being potential allies in museum design to create memorable experiences. The PERMA model, developed within the framework of Positive Psychology [54], provides a valuable lens for understanding how museum experiences shape emotional engagement and well-being. This model identifies five fundamental dimensions of psychological well-being: positive emotions, engagement, relationships, meaning, and accomplishment. Rather than serving as a rigid classificatory structure, PERMA functions here as an organisational heuristic that helps map the range of emotionally significant outcomes a well-designed museum experience can support — outcomes that will be traced across the subsections that follow. In the context of museum visits, these elements collectively contribute to enhancing both the immediate enjoyment of the experience and its long-term impact on cognitive and emotional growth. Among these dimensions, positive emotions play a particularly crucial role. Museums, through art, culture, and immersive experiences, have the potential to evoke emotions that are not only pleasurable in the moment but also transformative in the long run [55]. These emotional responses can enhance personal well-being, strengthen cultural appreciation, and create lasting psychological benefits [56]. Specifically, positive aesthetic emotions such as interest, joy, surprise, wonder, and contentment shape how visitors interact with exhibits. Additionally, epistemic emotions, such as curiosity and wonder, along with a range of positive aesthetic emotions that are epistemic in nature, further stimulate cognitive engagement, encouraging visitors to explore, reflect, and construct meaning from their experiences. This aligns with Barbara Fredrickson's broaden-and-build theory [57], which suggests that positive emotions expand individuals' cognitive and attentional capacities, promoting greater psychological resilience and well-being.

Wonder and awe, in particular, warrant specific attention as complex emotions characterized by perceived vastness — encountering something larger than oneself or one's existing schemas — and need for cognitive accommodation, whereby existing mental frameworks must expand to integrate the experience [58,59].

The following subsections examine four aspects through which emotions operate in museum contexts, each carrying its own implications for inclusive practice: the regulation of emotional states and the spatial strategies that support it; the epistemic emotions that drive active exploration and knowledge engagement; the dynamics of emotional contagion in shared, collective environments; and the opportunities and ethical responsibilities introduced by Extended Reality technologies in shaping visitor affect.

3.2.1. Reflection and emotional regulation

Museums can serve as ideal spaces for reflection, offering a carefully curated and controversial range of perspectives that provide food for thought that helps individuals temporarily distance themselves from potentially harmful emotional states [60]. Museums can design conditions that support ethically justifiable emotional aims (e.g., care, accountability, empathy) through transparent interpretive framing, promoting exploration and discovery, stimulating creative and open thinking, and facilitating a more reflective and immersive approach to art and culture [61]. In this sense, the ability to regulate one's emotions is crucial in a stimulus-rich environment like a museum. Emotional regulation refers to processes through which individuals monitor, evaluate, and modulate the intensity, duration, and expression of emotional experiences to achieve personal or social goals [62]. In museum contexts, effective emotional regulation enables visitors to sustain engagement, approach challenging or emotionally provocative content, and maintain psychological comfort across extended visits. Importantly, emotional regulation capacities vary substantially across visitors: neurodivergent individuals may experience emotions more intensely or process them atypically — as in alexithymia, which involves difficulty identifying and describing emotional states — while visitors with trauma histories may encounter specific environmental or content triggers that activate distress responses. Design strategies must therefore support emotional regulation across this full range of individual variation, not only for the normative visitor.

Practical design strategies that support emotional regulation include rest areas and pathways that facilitate a gradual progression through collections, helping visitors manage their emotional reactions and maintain psychological comfort across extended visits [44]. The first contact with the museum — such as the entrance or ticketing area — is crucial for setting a positive tone for the visitor experience [46]. A welcoming atmosphere that evokes curiosity and anticipation can predispose the visitor to an emotionally enriching experience from the outset, enhancing their ability to regulate emotions. Research by Packer and Bond demonstrates that positive priming during museum entry correlates with enhanced attentional capacity and increased cognitive flexibility during exhibit interaction [63]. Craggs and Schofield similarly found that initial environment-induced affect regulation impacts visitors' capacity to engage with challenging or emotionally provocative exhibits, with pre-primed positive states enabling longer engagement with complex material [64]. Entry conditions can influence subsequent engagement; therefore museums should ensure legibility, welcome, and informed choice at the outset. These design choices should be transparent and accountable, avoiding covert affective steering. Environmental and spatial interventions shape emotional tone through elements identified in Stress Recovery Theory: spatial openness reduces feelings of confinement and supports stress recovery; natural light and biophilic elements such as plants, water features, and natural materials enhance positive affect and reduce physiological stress markers; views toward nature or calming vistas provide emotional respite [65,66]. Colour can influence arousal and mood, although these effects are context-dependent and culturally mediated. Museums should therefore prioritise visitor testing rather than rely on universal prescriptions. Highly bright, saturated reds and oranges tend to increase arousal and may feel aggressive when overused, whereas softer blues and greens are generally associated with calm. Warm earth tones are often perceived as grounding and secure [67].

Providing content warnings, alternative routes around potentially distressing material, and clearly visible exit options further supports emotional regulation by respecting visitors' autonomy and their right to manage their emotional engagement. While this principle is broadly applicable, it is particularly important for visitors with trauma histories or heightened emotional sensitivity [68].

3.2.2. Epistemic emotions and active exploration

While aesthetic emotions are typically associated with the appreciation of beauty and artistic expression, they also serve an important epistemic function by facilitating cognitive engagement and deeper understanding. As already mentioned, emotions such as surprise, curiosity, and wonder are central to this process, as they are directly linked to cognitive activities involving knowledge acquisition, interpretation, and intellectual exploration [69,70]. A museum that stimulates curiosity not only draws attention to its objects but also invites visitors to delve deeper, asking questions and seeking answers that expand their understanding of the world. Surprise occurs when encountering something unexpected, an element that breaks habitual thought patterns and offers new perspectives. Wonder, on the other hand, is often associated with extraordinary beauty, evoking a profound sense of awe and connection with the content of the experience [71].

Museums can invite epistemic emotions (curiosity, wonder) through interpretive choices while recognising that responses are plural contested, and visitor-led, fostering an environment that not only captivates visitors but also encourages cognitive and affective engagement. Research suggests that curiosity can be stimulated through moderate levels of informational gaps — situations where visitors recognise they lack knowledge but feel motivated to resolve this uncertainty [72].

Interactive and open-ended exhibit designs, where visitors are encouraged to make predictions, engage in problem-solving, or compare perspectives, have been shown to enhance curiosity-driven exploration. Similarly, surprise plays a pivotal role in reshaping cognitive schemas by disrupting expectations and prompting re-evaluation [73]. Effective exhibition strategies that incorporate unexpected juxtapositions, hidden details, or unconventional narratives can enhance this effect. Studies on aesthetic experience suggest that the violation of expectations, when balanced with coherence and meaning, can result in a pleasurable engagement that deepens interpretative efforts. Wonder, in contrast, encompasses an overwhelming emotional and cognitive response to stimuli perceived as vast, complex, or extraordinary [74]. Encounters with awe-inspiring artworks or grand architectural spaces can induce a sense of cognitive accommodation, where existing mental frameworks are expanded to integrate novel experiences [75]. Museums can enhance this effect by utilising scale, lighting, and spatial arrangements that emphasise grandeur, as well as by curating narratives that highlight the vastness and mystery of the subject matter. The design of epistemic emotion, however, must remain attentive to individual variability: the informational gaps that trigger productive curiosity in one visitor may generate anxiety or disengagement in another, particularly for visitors with lower prior knowledge, cognitive processing differences, or low tolerance for ambiguity. Calibrating the intensity and framing of epistemic challenges to accommodate diverse visitor profiles is therefore not a peripheral concern but central to the effectiveness of curiosity-driven design.

3.2.3. Emotional resonance in shared museum environments

Since cultural experiences at museums are often collective, the phenomenon of emotional contagion — where emotions spread from one individual to others, significantly impacting group dynamics — warrants careful attention in museum design [76]. Emotional contagion operates through unconscious mimicry and physiological synchronisation [77]: positive contagion can amplify joy, wonder, and engagement as group members feed each other's enthusiasm; negative contagion can spread frustration, boredom, or anxiety. Several studies demonstrate that emotions can transfer between individuals in a group, influencing overall group behaviour, cooperation, and performance [78], underlining that emotionally charged environments can lead to synchronised emotional states among group members that affect their interactions and collective outcomes.

Museums can make room for collective experiences, while ensuring equally resourced solitary pathways. Research in educational and cultural psychology indicates that learning in social contexts fosters higher motivation, deeper comprehension, and longer retention of information. Museums could design guided tours for small groups, family-oriented visits, or interactive team-based activities, ensuring that visitors engage with exhibits not only as individuals but also as part of a socially connected unit. Museum educators could facilitate discussions that prompt visitors to articulate their emotions and insights, reinforcing both individual reflection and shared interpretation. Another effective strategy is the incorporation of collaborative tasks — such as solving exhibition-related puzzles, participating in co-creative art activities, or engaging in role-playing scenarios — which foster emotional engagement and improve cognitive outcomes [79]. Interactive exhibits that require two or more participants to work together, such as augmented reality experiences, co-narrated storytelling tasks, or multi-user digital interfaces, can amplify the effects of emotional contagion and social learning. Designing museum pathways to encourage spontaneous social interactions — through strategically placed discussion prompts, interactive installations, or comfortable seating in key locations — can further facilitate sharing among visitors [46].

These social design strategies must, however, account for the full diversity of visitors' social and emotional capacities, a consideration that is structural rather than supplementary. Some visitors — including many neurodivergent individuals, those with social anxiety, or those from cultural backgrounds with different norms around public emotional expression [80] — may find group-based emotional experiences uncomfortable or inaccessible rather than enriching. Cultural differences in emotional expression and regulation are particularly relevant here: norms around public emotional display, preferences for solitary versus social emotional processing, and meanings attached to specific emotions vary across cultural contexts in ways that museum design should not presuppose. Inclusive emotional design therefore requires offering meaningful alternatives to collective engagement alongside group-based experiences: quiet zones for individual reflection, self-directed pathways that do not require social participation, and interpretive content that supports emotional resonance without requiring its public performance.

3.2.4. XR technologies and emotional engagement

The emotional dimension of museum experience is also shaped by Extended Reality (XR) technologies, whose capacity to modulate and intensify emotional states introduces both significant opportunities and ethical responsibilities that are inseparable from one another. The “Positive Technology” framework, derived from Positive Psychology, promotes the design context-appropriate digital experiences that integrate, augment, and contextualise material encounters - rather than replace the real environment with virtual elements - to enhance experience quality and psychological wellbeing [81]. A practical application of this framework in museums is the “Variable Virtuality Exhibition Spaces” (SEVV) — spaces designed to enhance, enrich, and improve the museum experience through the targeted use of extended reality [82]. SEVV are designed to increase sensory, emotional, and cognitive engagement while considering neurodiversity and possible sensory and motor limitations to ensure an inclusive and accessible experience. Key XR components, such as multisensory interaction, biofeedback, and the integration of virtual objects overlaid onto real ones, are essential for creating a high sense of presence, immersion, and emotional engagement. VR and AR, in particular, are proven technologies for inducing positive emotions such as joy and relaxation [83], as well as complex emotions like awe and the sublime. SEVV, potentially supported by artificial intelligence, leverages these technologies to offer an enriched and personalised museum experience capable of engaging all visitors.

However, the emotional affordances of XR and their ethical risks are not separable. Unlike traditional media where emotional intensity can be modulated by looking away or stepping back, VR's immersive nature makes disengagement more difficult, potentially trapping visitors in distressing experiences. This risk is unevenly distributed across visitor populations: individuals with anxiety disorders or trauma histories may be retraumatised by intense VR scenarios, and children may lack the emotional regulation capacities to manage distressing content [84]. These vulnerabilities are compounded by the individual variability in emotional processing discussed in the preceding subsections — visitors who experience emotions more intensely, or who process them atypically, face heightened exposure to XR's risks alongside its benefits. Ethical XR implementation is therefore not an optional supplement to emotional design but a structural requirement of it. Robust informed consent with clear advance description of emotional content and intensity, easy and visible exit options, and access to trained staff for post-experience support are constitutive features of responsible emotional XR design [85], not precautionary additions to be considered after the fact.

3.3. The cognitive dimension

The cognitive dimension covers various aspects, including learning, attention, thinking and reasoning, language, and all those mental processes that promote individual growth in terms of critical thinking, creativity, and the ability to apply learned content in other contexts. This dimension is grounded in Kaplan's ART theory [11] — introduced in Section 2 as a foundational theoretical tradition and revisited here for

its specific implications for cognitive design — which reveals that cognitive engagement requires scarce attentional resources that can be depleted through effortful concentration and restored through appropriate environmental conditions. Museum visits inherently demand sustained directed attention for reading labels, following narratives, making connections across objects, and navigating spaces. When attentional resources are exhausted through cognitive overload or poor environmental conditions, visitors experience museum fatigue: reduced engagement time, superficial rather than deep processing, decreased memory formation, and irritability [10]. Restorative design that provides soft fascination — objects, narratives, and spatial qualities that gently engage attention without demanding effort — spatial coherence, and psychological distance from everyday demands enables cognitive resource replenishment, sustaining engagement across extended visits. Complementing this, Cognitive Load Theory (CLT) [86,87] distinguishes between intrinsic load (the inherent complexity of content itself), extraneous load (unnecessary demands imposed by poor design such as confusing spatial layouts, illegible labels, visual clutter, or navigation ambiguity), and germane load (productive cognitive effort that builds understanding and schema development). Effective museum design minimises extraneous load while optimising germane load through scaffolding strategies, layered interpretation that accommodates different expertise levels, and pacing that allows cognitive consolidation.

The cognitive dimension is vast, and a comprehensive treatment of all its constituent processes lies beyond the scope of a single article. The following subsections therefore focus on learning as the central cognitive outcome of museum experience — a choice motivated by its direct relevance to museum design and its integrative relationship with attention, memory, and meaning-making. Hein argues that learning is an active process that builds meaning from sensory inputs, is contextual, and is closely linked to language and motivation [2,3]. Individuals can assimilate not only content but also the processes by which learning occurs, and learning is a long-term process shaped by repeated exposures in which prior knowledge influences the integration of new information. This aligns with constructivist frameworks positioning visitors as active constructors of knowledge who integrate new information into existing cognitive schemas through processes of assimilation — fitting new information into current frameworks — and accommodation — modifying frameworks to incorporate novel information [88]. Learning is not passive reception of transmitted knowledge, but active construction shaped by prior knowledge, motivations, social interactions, and physical context.

3.3.1. *Optimising visitors' attentional processing and learning*

A first challenge for cognitive design concerns the relationship between the quantity of objects and the depth of engagement they afford. Vertecchi argues that the overwhelming quantity of objects presented to museum visitors can dilute attention, leading to perceptual saturation — a state in which excessive stimuli result in disengagement or even rejection [89]. Narrowing visitors' focus to a select number of exhibits allows for deeper engagement and more meaningful learning, moving away from passive, fleeting perceptions toward a structured network of learning opportunities that can become part of an individual's broader cultural identity. Falk and Dierking reinforce this by emphasizing that learning is inherently contextual, shaped by free-choice exploration and extending well beyond the time spent within the museum [90]. Knowledge is closely tied to the environment in which it is acquired, and a key challenge for museum design is therefore facilitating the transfer of learning from the museum setting to other domains. Research suggests that motivation increases significantly when individuals engage with environments that actively support knowledge acquisition [91] — support best provided through activities that stimulate curiosity and offer a sense of purpose, making learning both enjoyable and applicable across contexts [92].

A second challenge concerns the calibration of cognitive difficulty. Overly simplistic experiences risk inducing boredom, while excessively difficult ones lead to frustration. Studies suggest that introducing moderate novelty and complexity triggers prediction errors, enhancing cognitive engagement and learning [74]. In museum curation, this principle aligns with strategies that blend familiarity with surprise, prompting visitors to explore, make connections, and refine their interpretations. This process mirrors the well-documented "Aha" moment, in which resolving ambiguity fosters intellectual satisfaction and deeper understanding [73]. Museums can facilitate progressive sense-making through interactive problem-solving and layered interpretations [47]: as visitors refine their ability to recognise patterns over time, their aesthetic and intellectual appreciation deepens. Structured yet unpredictable stimuli — a principle supported by findings in music cognition research — enhance engagement and comprehension, and by subtly challenging perception, museums encourage repeated interaction that reinforces both cognitive and aesthetic dimensions of experience [74].

A third challenge concerns the social and environmental conditions of learning. Learning is fundamentally social, constructed through dialogue, shared emotions, gestures, and observational learning [90]. Visitors often navigate exhibits within groups — families, school classes, peer cohorts — where social interactions mediate meaning-making. Modelling and storytelling are particularly effective in this regard, allowing visitors to engage with content in narrative-driven and experiential ways. The physical environment itself also shapes cognitive engagement: first-time visitors often devote significant attentional resources to orienting themselves, and both extreme novelty and excessive familiarity reduce motivation to engage, whereas moderately novel stimuli encourage exploration and sustained interest [91,92]. Cognitive inclusivity must be treated as a structural principle within this context rather than a supplementary accommodation. Neurodivergent visitors benefit from multiple pathways to understanding: some process visual information efficiently but struggle with dense text — as in dyslexia or certain autism presentations — while others excel in verbal processing yet find visually complex environments overwhelming, as can occur in some ADHD profiles [93]. Providing redundant interpretive content across modalities — textual, visual, auditory, and tactile — supports access across cognitive strengths, while clear structure and predictability reduce cognitive load for visitors with executive function challenges [94]. Cognitive inclusivity also intersects with cultural and linguistic diversity: multilingual interpretation is essential, as are universal design principles such as clear visual communication, logical spatial organisation, and layered conceptual explanations that do not presume specific cultural background knowledge [95]. Participatory interpretive approaches that invite multiple perspectives further reinforce cognitive accessibility by legitimising diverse ways of making meaning rather than imposing a single authoritative interpretive frame.

These three challenges — managing quantity and depth, calibrating difficulty, and designing for social and environmental diversity — converge on a shared design implication: museums that offer structured opportunities for focused, appropriately challenging, and socially supported engagement create the conditions under which genuine cognitive growth becomes possible. Practically, this includes dedicated silent areas and scheduled quiet hours that provide continuous access to low-stimulation environments where visitors can engage in focused contemplation [89], designed with acoustic treatments and spatial buffers to maintain consistently reduced auditory stimulation. These provisions are not peripheral amenities, but expressions of the same cognitive design principles articulated throughout this section.

3.3.2. *Cognitive affordances and constraints of XR technologies in museum learning*

XR technologies offer distinctive cognitive affordances unavailable through traditional interpretive media, particularly by enabling forms of embodied, spatial, and situated cognition. Virtual reality supports first-person perspective-taking and active spatial exploration, facilitating cognitive processes such as mental rotation, spatial reasoning, and

embodied understanding of scale and relational structure, enabling visitors to construct mental models through navigation rather than passive observation [96]. Visiting a historical site in VR, for example, allows learners to actively explore spatial configurations and causal relationships, fostering deeper conceptual integration. Augmented reality enhances cognition primarily through in-situ scaffolding: by layering explanatory information directly onto objects or environments, AR reduces the cognitive load associated with mentally linking labels to artefacts or remembering connections across spatially separated elements [97]. AR can further support comparative and analytical reasoning by revealing otherwise invisible structures — such as archaeological reconstructions superimposed on fragmentary remains, anatomical layers within specimens, or temporal change visualised through historical images overlaid on present-day locations.

The value of these affordances, however, depends critically on how well XR design accounts for variability in cognitive profiles, prior technological familiarity, and processing styles across the visitor population — and the risks that arise when this variability is not adequately addressed are inseparable from XR's cognitive opportunities. Cognitive overload is a central concern: poorly designed VR environments characterised by excessive information density, ambiguous objectives, or disorienting navigation can overwhelm working memory and generate confusion rather than understanding [98]. The novelty of immersive technologies can itself divert attentional resources, producing split-attention effects in which cognitive effort is expended on mastering the interface rather than engaging with interpretive content [99]. These risks are amplified for visitors with executive function challenges — common among individuals with ADHD, autism, or specific learning disabilities — who may experience open-ended virtual environments without clear structure as cognitively paralysing rather than exploratory [100]. Effective XR learning design therefore requires clearly articulated learning goals, intuitive interfaces with minimal technological learning overhead, scaffolded complexity that increases progressively, and close alignment between technological affordances and genuine interpretive needs. Additionally, some evidence suggests that intense sensory immersion may paradoxically reduce reflective and analytical engagement, with visitors becoming absorbed in experience at the expense of interpretive abstraction and transfer [101] — implying that optimal XR integration may depend on combining immersive exploration with structured reflective prompts, facilitated discussion, or post-experience interpretation that consolidates learning.

3.4. The motivational dimension

The motivational dimension of the visitor experience explores factors influencing museum visits and return intentions [102]. In psychology, motivation drives behaviour toward specific goals, shaped by environmental conditions. It explains why individuals engage or disengage from actions [103]. This dimension is grounded in Self-Determination Theory (SDT) [104,105], which identifies three fundamental psychological needs whose satisfaction sustains intrinsic motivation in free-choice learning environments. Autonomy is the need to experience choice, volition, and self-direction rather than feeling controlled or coerced. Museums support autonomy by offering multiple pathways through exhibitions, allowing visitors to determine their own pace and focus, and respecting diverse reasons for visiting rather than imposing singular purposes. Competence is the need to feel effective and capable of mastering challenges. Museums support competence through appropriately scaffolded content that balances accessibility with challenge, through clear wayfinding that prevents disorientation, and through interpretive strategies that enable understanding without requiring expert knowledge. Relatedness is the need for connection — to other people, to communities, to ideas or values that matter. Museums support relatedness through socially engaging experiences, through content that connects to visitors' lives and identities, and through narratives that link individual objects to broader human concerns [106]. Crucially, these three needs are not uniformly supported by standard museum design: rigid prescribed pathways violate autonomy; inaccessible content or overwhelming complexity violates competence; cultural alienation or social isolation violates relatedness. The motivational dimension therefore intersects with all design decisions and must be evaluated across the full diversity of the visiting public, not only for the normative visitor.

3.4.1. Intrinsic motivation, flow, and motivational design in museums

Motivation is categorised as intrinsic — driven by curiosity, enjoyment, and self-expression — or extrinsic, based on external rewards or avoidance of punishment [107]. While intrinsic motivation fosters learning and persistence, extrinsic motivators can initiate behaviour but carry significant risks: when activities become associated with external rewards, internal interest can diminish through the overjustification effect [108,109]. This distinction has direct design implications: museums should prioritise intrinsic motivation through experiences that are inherently interesting, meaningful, and satisfying, recognising that genuine cultural engagement cannot be sustained through extrinsic mechanisms alone, and that gamification strategies must be deployed with particular care to avoid displacing the very intrinsic interest they are intended to support.

Studies on aesthetic experience suggest that intrinsic motivation plays a central role in the enjoyment of art, linked to the activation of the brain's reward circuitry — including the ventral striatum and orbitofrontal cortex — which responds to the perceived value and emotional salience of artworks [19]. Curiosity, the desire to seek novel information, further engages the dopaminergic reward system, reinforcing continued exploration and learning.

The highest level of intrinsic motivation is described as the “optimal experience” or “flow” experience [110]. Flow is characterised by total immersion in an activity in which the individual experiences high concentration, clear goals, and a fusion between action and awareness, producing intrinsic pleasure. It occurs when challenge and skill are in balance: when challenge exceeds skill, anxiety results; when skill far exceeds challenge, boredom results [111]. Museums can facilitate flow through experiences that provide clear objectives — what to look for, do, or understand — immediate feedback through responsive interactive elements, and appropriate challenge calibration. Flow represents one particularly intense form of intrinsic motivation, but it is neither the only form nor always the most appropriate motivational state for museum contexts. Contemplative engagement, social connection, emotional resonance, and gentle curiosity all constitute meaningful forms of intrinsic motivation that museums can and should support — and for many visitors, particularly those who find intense immersion cognitively or emotionally demanding, these quieter motivational states may be more accessible and ultimately more sustaining than flow itself.

Inclusive motivational design requires recognising that different individuals bring fundamentally different motivational structures to museum visits. Falk's visitor identity categories [112] — explorers seeking intellectual stimulation, facilitators supporting others' learning, experience seekers desiring novel activities, professionals conducting research, rechargers seeking restoration, and respectful pilgrims honouring heritage — illustrate this diversity, and inclusive museums create conditions that support multiple motivations simultaneously rather than designing for a single normative profile. Neurodivergent visitors may experience motivation differently: some autistic individuals show intense focused interest in specific topics that can drive deep, sustained engagement when museum content aligns but result in disengagement when it does not [113], and museums can support this motivational style by providing pathways for deep dives rather than requiring broad surveys. Individuals with ADHD may struggle with sustained attention but thrive with frequent novelty and varied interaction modes [114]. Cultural differences in motivation should also inform design: collectivist orientations may prioritise relatedness and social motivations over individual autonomy, and different cultural backgrounds may involve varying levels of comfort with participatory or playful engagement

modes [115]. These differences are not peripheral considerations but constitute the motivational landscape that museum design must navigate if it is to support genuine and sustained cultural engagement across its full public.

The relationship between the three SDT needs and the diversity of visitor motivational profiles converges on a shared design implication: experiences that support autonomy, competence, and relatedness foster sustained intrinsic motivation, while those that undermine any of these needs diminish engagement in ways that are unevenly distributed across visitor populations. Spatial layout affects autonomy; cognitive scaffolding affects competence; emotional warmth and inclusive representation affect relatedness. Motivational design is therefore not a discrete design category but a dimension that runs through every other aspect of the museum experience discussed in this framework.

3.4.2. XR technologies and motivational engagement

The integration of Extended Reality (XR) technologies can further enrich the motivational dimension of museum experience by allowing visitors to interactively explore collections, observe historical evolution, and access additional contextual information. VR's immersive presence creates inherent motivational pull: the novelty and sensory richness of being transported to another place or time activate reward systems and sustain attention [116]. These digital enhancements can amplify curiosity-driven learning by activating reward-related brain regions, reinforcing the motivation to engage with museum content [117]. Gamification elements within XR — such as collecting virtual artefacts, solving puzzles to unlock content, or achieving mastery badges — can provide motivational structure that some visitors, particularly younger audiences, find engaging, while adaptive XR systems that adjust difficulty based on user performance can maintain the challenge-skill balance that supports both flow and competence.

The motivational risks of XR are, however, as significant as its affordances. Overreliance on technological novelty risks creating engagement that is device-driven rather than content-driven: visitors may be motivated by the experience of VR itself rather than by genuine interest in cultural content, producing shallow engagement that does not transfer to broader museum appreciation or cultural participation [118]. Gamification carries the specific risk of undermining intrinsic motivation through the overjustification effect: when museum engagement becomes associated with collecting points or achieving levels, the inherent interest in culture may diminish [119]. Adaptive systems that adjust experience based on detected disengagement — through attention tracking or biometric monitoring — risk behavioural steering that undermines visitor autonomy, informed consent and curatorial accountability rather than respecting visitor autonomy and authentic interest. Perhaps most critically from an equity perspective, expensive XR implementations risk creating motivational inequity: visitors without access to required devices may experience their visit as second-class, violating both competence — feeling unable to access the best content — and relatedness — feeling excluded from what others can experience [120]. Ethical XR integration must therefore ensure that core content and motivational support are available through multiple modalities, with XR functioning as enhancement rather than gatekeeper.

3.4.3. Visitor expectations, motivational loops, and the hierarchy of visitor need

Visitor expectations shape motivation and engagement before the museum visit even begins. Expectations influence attitudes toward exhibits, objects, and ideas, as well as overall satisfaction with the experience. Providing visitors with pre-visit information about exhibition themes and key objects enhances engagement and retention [47], a practice that aligns with research indicating that anticipation and predictability enhance reward-related responses in the brain, thereby increasing motivation. Positive emotional states during visits further reinforce motivation through what can be described as a motivational loop: past positive experiences increase the likelihood of future cultural participation [121], and museums can cultivate these loops through immersive storytelling, structured welcoming moments that facilitate psychological transition into the exhibition, and reflective concluding segments that reinforce learning and emotional connection [122].

A complementary perspective on the hierarchy of visitor motivational needs can be drawn from Maslow's hierarchy of needs [123]. When adapted to the museum context, this framework highlights the enabling conditions that support participation — such as comfort, safety, legibility, belonging, and agency — while acknowledging that these needs may not follow a strictly linear progression and can vary across cultural contexts. At the foundational level, physiological needs — rest areas, cafeterias, comfortable temperatures — must be met before higher-order engagement becomes possible. Safety needs require a tranquil, legible, and psychologically secure environment. Belonging needs are addressed through engaging narratives and socially connected experiences that make visitors feel part of a shared cultural community. At the highest level, esteem and self-actualisation needs can be met through exhibits that challenge visitors intellectually and provide genuine opportunities for personal growth, reinforcing long-term motivation for cultural participation. This hierarchical perspective complements SDT by clarifying that motivational design is not only about the quality of the experience offered, but about ensuring that the foundational conditions for engagement are in place — conditions whose absence will undermine even the most carefully designed interpretive content.

3.5. Cross-dimensional dynamics: integration and interdependence

The four psychological dimensions — sensory-perceptual, emotional, cognitive, and motivational — operate as a dynamic, interdependent system rather than as isolated targets for optimisation [57,104]. Effective museum design requires understanding not only the distinct mechanisms within each dimension but also their reciprocal relationships, feedback loops, and emergent properties. Sensory-perceptual processes form the foundational layer: environmental features are first registered perceptually before shaping emotional states, cognitive processing, and motivational orientations [44,45]. Spatial openness, for example, is initially perceived visually and proprioceptively, but subsequently reduces stress, supports cognition by improving wayfinding and reducing cognitive load, and enhances motivation by increasing perceived autonomy and control [44,86]. Similarly, multisensory integration can either facilitate efficient processing when cues are congruent or increase cognitive load when sensory information conflicts [49,99].

Emotional states modulate all other dimensions by shaping attentional breadth, cognitive flexibility, and motivational orientation [57]. Positive affect broadens attention, supports creative cognition, and strengthens approach motivation, whereas stress and anxiety narrow attention, impair working memory, and promote disengagement [11,57]. Emotional regulation capacity therefore determines whether visitors can tolerate cognitive challenge and ambiguity or disengage prematurely [62]. Emotions also influence memory consolidation, with emotionally salient experiences more likely to be retained and integrated over time [57]. Cognitive processes, in turn, guide perception, emotion, and motivation: attention directs perceptual focus, cognitive appraisals shape emotional responses, and successful meaning-making generates positive affect and reinforces motivation. Motivational states regulate the allocation of perceptual and cognitive resources [104,110]: intrinsically motivated visitors sustain attention longer and invest more effort in interpretation, while satisfaction of autonomy, competence, and relatedness supports cognitive flexibility and emotional resilience. Experiences that undermine these needs can trigger disengagement even when other dimensions are well supported [104].

Understanding these reciprocal relationships enables cross-dimensional design strategies that produce synergistic effects. Design choices such as spatial openness, natural light, biophilic elements, and

quiet contemplation zones simultaneously support perception, emotion, cognition, and motivation [11,65]. Well-designed XR experiences can function similarly — supporting embodied perception, emotional engagement, cognitive scaffolding, and motivational curiosity — provided they remain optional, cognitively legible, and emotionally safe [52,84,99].

Inclusive design is inherently cross-dimensional, and this has implications that go beyond the accommodation of named disabilities or specific visitor groups. Visitors differ widely in sensory sensitivity, cognitive capacity, emotional regulation, motivational orientation, and cultural background, and these differences interact across dimensions in ways that are not always predictable from any single dimension alone. A visitor whose sensory hypersensitivity is well accommodated may still disengage if the motivational design presupposes a level of prior cultural familiarity that violates their sense of competence; a visitor whose cognitive needs are met may still struggle if the emotional design fails to provide adequate regulation support. Effective inclusion therefore does not consist in optimising each dimension separately for a broader range of profiles, but in designing the relationships between dimensions with the same care devoted to each dimension individually — providing flexibility, choice, predictability, and multiple pathways of engagement that work together as a coherent system rather than as parallel accommodations.

3.6. Synthesis: Translating psychological dimensions into design practice

The four-dimensional framework translates psychological theory into actionable design practice through a systematic approach that links each dimension to specific design levers while recognising their interdependence. Table 1 provides a comprehensive synthesis of how each psychological dimension maps onto concrete design principles, illustrative implementation strategies, and expected outcomes grounded in empirical evidence. This synthesis demonstrates that effective museum design requires simultaneously addressing multiple psychological needs through strategically selected interventions that create synergies across dimensions rather than optimising each dimension in isolation.

4. Conclusions

Cultural institutions — museums, theatres, historical sites — serve simultaneously as custodians of collective memory and as sites of ongoing cultural renewal. Their value lies not only in preserving artefacts, narratives, and traditions that define societal identities [124], but in their capacity to transform those encounters with the past into experiences that generate meaning, foster reflection, and support personal and social growth in the present [125]. Transformative cultural experiences are characterised by their enduring influence: they continue to shape perception and understanding long after the visit has ended, offering new frameworks through which visitors interpret themselves and the world [126]. Realising this potential, however, is not automatic — it depends on the deliberate design of experiences that cultivate personal relevance, emotional engagement, and active meaning-making [127–129]. It is precisely this dependency on design that motivates the framework proposed in this paper.

The four-dimensional framework — organised around sensory-perceptual, emotional, cognitive, and motivational dimensions — addresses a critical gap in museum scholarship and practice by systematising psychological mechanisms that existing models leave implicit or treat as secondary. The framework advances beyond visitor typology models, learning outcome frameworks, and experiential phase models through four defining characteristics. First, it directly links each dimension to specific design levers spanning environmental interventions such as spatial layout, lighting, and acoustic design; curatorial strategies including object selection, interpretive layering, and pacing; and technological affordances encompassing extended reality, interactive media, and adaptive systems [130,131]. Second, it foregrounds the interdependence of dimensions, treating cross-dimensional effects not as incidental side benefits but as central opportunities for strategic design that efficiently addresses multiple psychological needs simultaneously — as demonstrated in Section 3.5, where environmental interventions such as spatial openness were shown to influence sensory perception, emotional stress, cognitive load, and motivational autonomy concurrently. Third, it positions itself as a flexible conceptual scaffold adaptable across diverse museum types, institutional contexts, visitor populations, and cultural settings with distinct regional norms, accessibility standards, and participatory traditions [79,118,127]. Fourth, it integrates inclusive design as a cross-dimensional imperative, recognising that neurodivergent visitors, trauma survivors, and culturally diverse audiences require simultaneous attention to sensory modulation, emotional safety, cognitive clarity, and motivational alignment — not sequential accommodation across isolated dimensions.

Looking forward, the integration of digital and XR technologies opens significant possibilities for the personalisation of museum experience, with individual needs and preferences increasingly central to the design of digitally enhanced cultural spaces. However, responsible technology integration requires confronting critical concerns around authenticity, equity, agency, and sustainability. XR must enhance rather than replace authentic material encounter, ensure equitable access through non-technological alternatives that provide substantive content equity, respect visitor agency through meaningful informed consent and transparent algorithmic governance, and account for environmental costs while justifying technology use through clear educational value [132–134].

These possibilities must, however, be considered alongside a set of substantive critical perspectives that the framework does not resolve and that warrant explicit acknowledgement. A first concerns the evidential basis of claims linking museum experience to wellbeing and psychological growth. Several researchers have questioned both the magnitude of art-related wellbeing effects and the methodological robustness of studies examining them [135], raising concerns about publication bias, the reliance on self-report measures, and the difficulty of isolating museum-specific effects from broader social and contextual factors. The framework proposed here is not immune to these concerns: its design principles are grounded in empirical literature, but the translation from controlled experimental findings to complex, ecologically valid museum environments involve inferential steps that require empirical validation rather than assumption. A second critical concern relates to the risk that experience design — however psychologically sophisticated — may inadvertently prioritise affective engagement and visitor satisfaction over the deeper, sometimes uncomfortable, intellectual and moral work that genuine cultural encounter demands. A museum optimised for positive emotional priming, flow facilitation, and motivational reinforcement may produce visitors who feel enriched without having been genuinely challenged. These tensions between psychological comfort and cultural rigour, between engagement and difficulty, cannot be dissolved by design — they must be held consciously as normative questions that inform curatorial and institutional decision-making alongside the psychological principles articulated here.

A further challenge concerns the applicability of the framework across the immense diversity of museum contexts. At the typological level, the specific design implications of each dimension differ substantially across art, science, history, and natural history museums in ways that the framework outlines in principle but cannot fully specify. At the geographical and institutional level, museum practices, visitor expectations, accessibility norms, and cultural attitudes toward participatory engagement vary significantly across regions and traditions, introducing boundary conditions that no single framework can anticipate. These limitations underscore the need for context-sensitive application rather than wholesale adoption of the framework's design principles, and they define a clear agenda for future research.

Empirical validation represents the most pressing research priority.

Table 1
Four-dimensional framework: Psychological processes, design principles, and implementation strategies.

Dimension	Psychological Process	Design Principle	Implementation Example	Expected Outcome
Sensory-Perceptual	Multisensory integration [44,86]	Provide semantically congruent sensory cues across modalities	Textile exhibition combining visual displays, tactile fabric samples, soundscape of looms, and subtle scent of natural fibres	Evidence suggests enhanced memory encoding and deeper material understanding through multimodal reinforcement [44]
	Embodied perception [31,32]	Choreograph viewing positions and movement opportunities to support embodied engagement	Sculpture positioned at eye level with sufficient space for circular movement; interactive digital model allowing three-dimensional rotation	Research indicates increased empathic connection and enhanced spatial understanding through embodied engagement [31]
	Spatial legibility [25,26]	Design unambiguous visual hierarchies and intuitive circulation routes	Distinct gallery entrances, visible sightlines to key objects, colour-coded zones, and strategically placed orientation maps	Reduced cognitive load and navigation stress, with more attentional resources available for interpretive content [25]
	Perceptual complexity management [10,27]	Balance novelty with coherence and avoid perceptual oversaturation	Curate 20–30 key objects with adequate visual breathing room rather than dense displays; alternate high-complexity zones with rest areas	Studies indicate sustained attention and reduced fatigue, enabling deeper engagement with individual objects [10]
	Acoustic design [49]	Differentiate sound environments to match cognitive and social functions of distinct spaces	Sound-absorbing materials in contemplation areas; ambient soundscape in immersive zones; acoustic separation between social and quiet spaces	Reduced physiological stress, improved concentration, and accommodation of diverse noise tolerance thresholds [49]
	Sensory regulation for neurodiversity [48,49]	Provide advance sensory information and designated low-stimulation spaces	Pre-visit guide specifying exhibition noise and light levels; dedicated low-stimulation room with adjustable dim lighting and minimal sound	Evidence supports reduced anxiety, increased visitor autonomy, and prevention of sensory overwhelm across neurodiverse populations [48]
Emotional	Positive emotional priming [63,64]	Design welcoming, curiosity-evoking entry environments that establish a positive affective schema	Entrance gallery with intriguing teaser objects, warm lighting, clear orientation information, and accessible staff	Research by Packer and Bond indicates enhanced attentional capacity and increased cognitive flexibility following positive entry priming [63]
	Stress recovery [24,65,66]	Integrate natural elements systematically to reduce physiological stress markers	Interior courtyard with plants and seating, natural materials including wood and stone, water feature, and natural light penetration	Evidence indicates reduced cortisol levels, lower heart rate, enhanced positive affect, and increased subjective restoration [65]
	Epistemic emotions [58,59]	Use scale, grandeur, or conceptual vastness to evoke awe while providing grounding alternatives	Monumental atrium with dramatic ceiling height and natural light; paired with human-scaled alcoves offering emotional containment	Research suggests expanded cognition and prosocial orientation following awe experiences [59]; grounding provisions necessary for visitors prone to overwhelm [58]
	Emotional regulation support [62,68]	Provide quiet spaces designed explicitly for emotional processing and recovery	Low-stimulation contemplation room with soft seating, adjustable dim lighting, views toward nature, and acoustic insulation	Evidence supports sustained engagement and prevention of emotional fatigue, particularly for visitors with anxiety or heightened sensitivity [62]
	Epistemic emotion [72,73]	Create moderate informational gaps structured to motivate rather than frustrate exploration	Interactive exhibit posing a specific intriguing question whose answer is revealed through visitor investigation; unexpected object juxtapositions with interpretive scaffolding	Studies indicate increased exploratory behaviour, deeper cognitive engagement, and strengthened intrinsic motivation [73]
	Emotional contagion [76,77]	Design social spaces that facilitate shared emotional expression without requiring participation	Family activity stations encouraging collaborative creation alongside quiet individual alternatives; discussion circles with optional participation prompts	Research indicates amplified joy and wonder through positive contagion, strengthened social bonds, and enhanced memory through shared narrative [77]
	Affective design [68]	Provide content warnings, alternative pathways, and emotional support for difficult material	Advance signage before exhibitions containing disturbing imagery; alternative less-graphic pathway; trained staff availability; designated quiet processing space afterwards	Evidence supports enhanced emotional safety, visitor autonomy, and prevention of retraumatisation [68]
Cognitive	Attention restoration [10,11]	Provide soft fascination and spatially coherent environments that enable attentional recovery	Gallery with carefully selected objects, visual breathing room, natural light, clear thematic coherence, and seating for contemplation	Research indicates sustained attention, reduced mental fatigue, and deeper engagement with individual objects following restorative design [11]
	Cognitive load management [86,87]	Minimise extraneous load through clear spatial and informational design	Intuitive wayfinding with visual landmarks, legible labels calibrated to appropriate reading level, and layered interpretation offering brief and extended options	Evidence supports increased cognitive resources available for learning, reduced frustration, and longer engagement time [86]
	Constructivist scaffolding [88,90]	Support active meaning-making through appropriately challenging interpretive tasks	Interactive prompting visitors to compare art movements across cultures with guided questions, without prescribing a single authoritative interpretation	Research suggests deeper understanding, greater ownership of learning, and development of transferable interpretive skills [88]
	Visual literacy development [36,37]	Facilitate sustained observation and evidence-based reasoning through structured inquiry	Visual Thinking Strategies facilitation: open-ended questions including “What is going on?”, “What makes you say that?”, and “What else can we find?"	Studies indicate enhanced critical thinking, increased comfort with interpretive ambiguity, and development of transferable analytical skills [36]
	Social collaborative learning [79,80]	Create structured opportunities for co-constructed understanding across visitor groups	Family activity stations with guided discussion prompts; educator-facilitated small group dialogues; collaborative problem-solving tasks requiring multiple participants	Evidence indicates richer interpretations through multiple perspectives, strengthened social bonds, and enhanced memory through shared narrative construction [80]
	Optimal cognitive arousal [73,74]	Balance familiar contextual anchors with strategically placed surprising elements	Exhibition on a familiar historical period incorporating unexpected object juxtapositions that reveal unfamiliar perspectives	Research suggests prediction error engagement, schema revision, and generation of memorable insights [74]
	Cognitive consolidation [11,89]	Provide designated low-stimulation spaces supporting	Silent gallery with acoustic treatment, soft seating, minimal visual distractions, and clear signage requesting quiet	Evidence supports enhanced memory formation and reduced cognitive overwhelm, particularly for neurodivergent visitors [89]

(*continued on next page*)

Table 1 (*continued*)

Dimension	Psychological Process	Design Principle	Implementation Example	Expected Outcome
		focused attention and memory formation		
Motivational	Autonomy support [104,105]	Offer meaningful, clearly described choice over pathway, pace, and interpretive focus	Multiple thematic routes through exhibition — chronological, thematic, and by complexity level — with descriptions enabling informed visitor choice	Research indicates enhanced intrinsic motivation, increased sense of control, and more personalised experience [104]
	Competence support [104,106]	Scaffold interpretive content to balance accessibility with appropriate challenge	Layered interpretation offering overview, moderate detail, and deep-dive options; pre-visit primers for complex topics; interactive elements enabling progressive mastery	Evidence supports increased visitor confidence, reduced frustration, and sustained engagement with challenging material [104]
	Relatedness support [104,106]	Connect exhibition content explicitly to visitors' lives, identities, and communities	Contemporary art exhibition linking historical movements to current social issues; community voices and local histories integrated into interpretive content	Research indicates enhanced personal relevance, emotional investment, and sense of cultural belonging [106]
	Flow [110,111]	Balance challenge and skill with clear objectives and immediate feedback	Puzzle-based interactive with progressive difficulty calibration, immediate feedback on attempts, and visible progress indicators	Research suggests conditions for total absorption and optimal experience when challenge-skill balance is maintained [110]
	Positive anticipation [47,121]	Provide structured pre-visit information that builds expectations and reduces entry uncertainty	Pre-visit communication including exhibition highlights, intriguing teaser content, and practical information covering duration, accessibility, and available amenities	Evidence indicates increased anticipatory motivation, reward system activation, and reduced entry anxiety [121]
	Motivational feedback loops [121,122]	Design complete visit arc — entry, engagement, conclusion — to consolidate positive experience	Structured welcoming transition, engaging content supporting SDT needs throughout, and reflective concluding segment prompting explicit articulation of personal takeaways	Research indicates increased visitor satisfaction, positive long-term associations with museums, and higher likelihood of return and recommendation [122]

Longitudinal studies examining how interventions targeting multiple dimensions simultaneously compare to single-dimension approaches — in terms of visitor engagement, learning outcomes, wellbeing indicators, and return intentions — would provide crucial evidence for the framework's practical value and help identify the conditions under which cross-dimensional synergies are most reliably produced [136]. A complementary research priority concerns differential responses across visitor populations: understanding how individuals varying in age, cultural background, neurodiversity, prior knowledge, and motivational profile respond to cross-dimensional design strategies would enable more precise and genuinely inclusive design guidelines. Finally, examining the long-term impacts of psychologically informed museum experiences on cultural participation, identity development, and community wellbeing would illuminate the extent to which museums can function as transformative public institutions — not merely as sites of individual enrichment but as contributors to the social and cultural fabric of the communities they serve [137].

Use of AI-assisted language tools

The authors used artificial intelligence (AI) tools to support linguistic revision of this manuscript. Specifically, AI assistance was employed to refine sentence-level phrasing, improve grammatical clarity, and enhance overall readability. All intellectual content, argumentation, theoretical framing, and scholarly judgements remain entirely the work of the authors. The authors take full responsibility for the integrity and accuracy of the content as published.

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.

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