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Understanding VR-mediated empathy in design: measurement approaches, inconsistencies and implications

Xinhui Hu [1,2], **Hernan Casakin** [3] **and Georgi V. Georgiev** [1]

[1] *Center for Ubiquitous Computing, University of Oulu, Finland,* [2] *School of Information Sciences, University of Illinois at Urbana Champaign, USA,* [3] *Ariel University, Israel*

✉ georgi.georgiev@oulu.fi

ABSTRACT: Virtual Reality (VR) has garnered significant attention as a potential 'empathy machine' for its ability to simulate firsthand experiences of others' perspectives. However, recent research reveals conflicting evidence regarding VR's effectiveness in fostering empathy, with outcomes ranging from strong positive effects to complete ineffectiveness. By analyzing both subjective experiences and objective measures, this study aims to elucidate the relationship between VR design and human empathy, addressing three prevalent perspectives on the field's inconsistencies: flawed mechanisms, ineffective design, and mismatched methodology. The findings contribute to the theoretical understanding of empathic VR and provide practical implications for designing effective VR-based empathy interventions in engineering contexts.

KEYWORDS: virtual reality, user centred design, experience design, empathy, design methods

1. Introduction

For decades, designers have explored strategies to better understand users, pursuing an empathic understanding of the diversity of their perspectives and experiences (Koskinen et al., 2003; Leonard & Rayport, 1997). In design, empathy is the process of understanding users' experiences, emotions, and needs in their real-world context to create user-centred solutions. It involves both emotional resonance and contextual awareness, ensuring that design decisions align with users' lived realities rather than designers' assumptions. However, traditional imagination-based empathy approaches have been proven insufficient for these purposes (Hu et al., 2021), as designers often lack the lived experiences needed to fully contextualize users' cultural and personal concerns. Secondary and inquiry-based approaches do not necessarily resolve this issue, as designers inevitably interpret information through their own cognitive frameworks (Hu et al., 2021), resulting in misalignments with users' perspectives and priorities. Virtual Reality (VR) technology has emerged as a promising solution, acting as a "life simulator" that enables designers to develop experience-driven empathic understanding (Bertrand et al., 2018; Christofi et al., 2020).

VR's value as a research tool for empathy lies in its ability to simulate real-world situations while controlling any potential confounding factors (Bombari et al., 2015). VR recreates an individual's physical surroundings, sensory experiences, and perspective in a carefully controlled virtual environment, allowing operators to draw meaningful connections between their own and the simulated individual's perspectives (Bertrand et al., 2018; Christofi et al., 2020; Hu et al., 2021). This immersive experience is believed to provide a foundation for accurately understanding and interpreting the simulated individual's emotions, experiences, and viewpoints.

Recent literature has largely validated VR's effectiveness in simulating social interactions similar to those observed in real-world settings (Bombari et al., 2015; Slater et al., 2006) and shaping sensory perception through avatar embodiment (Banakou et al., 2013). However, how to design an effective empathic VR scenario to support design practice remains an open question, particularly given the ongoing dissonance in

the literature regarding the outcomes and design implications of VR-based empathy experiences (Trevena et al., 2024; Ventura et al., 2023). Researchers remain divided on several key issues: what types of empathy VR can elicit (Hu et al., 2023; Lee et al., 2024; Martingano et al., 2023), what design dimensions are essential for fostering empathic engagement (Barbot & Kaufman, 2020; Han et al., 2022), what design choices most effectively enhance empathy (Ahn et al., 2013; Bujic et al., 2020; Hu et al., 2023; Kors et al., 2016), and whether VR is inherently more effective than other media in eliciting empathy (Blythe et al., 2021; Sundar et al., 2017).

To bridge this critical gap, this study aims to shed light onto the complex relationship between VR design and human empathy, providing insights into key mechanisms involved and laying the groundwork for a cohesive theoretical framework to guide future research. By mapping where and how researchers diverge in their findings and interpretations and conducting a more precise examination of the factors driving these inconsistencies, our analysis reveals that these discrepancies stem from a complex interplay of influences. Specifically, they arise from divergent conceptualizations of empathy, varying interpretations of VR's potential and limitations, and methodological discrepancies shaped by differences in study scope, objectives, and evaluation frameworks. Upon identifying these sources of confusion, we propose a methodologically controlled experimental framework to empirically disentangle this complexity.

2. Empathy and VR

Before delving into the conflicting literature on empathic VR, it is essential to first clarify the concepts of empathy, VR, and empathic VR, as many inconsistencies stem from their conceptual ambiguity.

2.1. Empathy

Empathy integrates neural functions for recognizing, interpreting, and responding to emotions. Brain imaging studies identify at least five key neural systems that support empathy (Figure 1): (1) the affective emotion resonance system, which operates automatically via basic neural functions (Shamay-Tsoory et al., 2009); (2) a cognitive perspective-taking system, requiring effortful cognitive processing (Davis et al., 2004); (3) a visuomotor-based somatic system, activated by neural mirroring in response to pain or sorrow (Price & Dambha-Miller, 2019); (4) a compassionate empathy system, linked to prosocial behaviour and sometimes overlaps with sympathy(Cuff et al., 2016); and (5) an emotion-regulation system, located in the dorsolateral prefrontal cortex, regulates emotional responses for context-appropriate reactions (Hu & Georgiev, 2020).

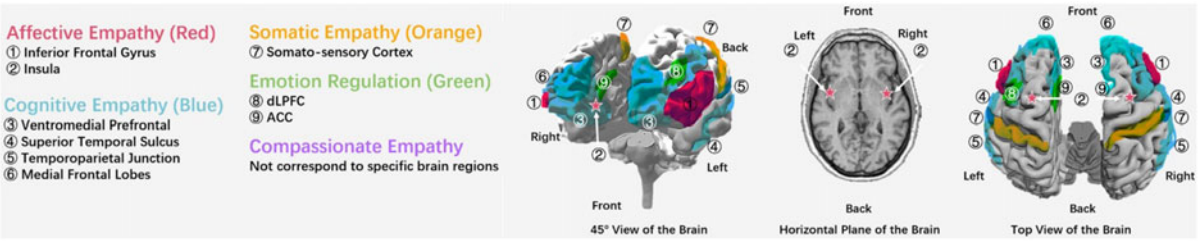

Figure 1. Brain systems underlying empathy

This neural complexity explains why empathy is framed variably—as a stable trait or dynamic state, an automatic response or deliberate process, an intrinsic ability or malleable skill (Barbot & Kaufman, 2020; Cuff et al., 2016; Hu & Georgiev, 2020). Emphasizing different neural mechanisms naturally alters the perceived properties of empathy across contexts. Thus, 'enhancing empathy' remains fluid, varying across studies and domains. (Lee et al., 2024; Ventura et al., 2023).

2.2. VR

Virtual Reality (VR) is commonly defined a simulated 3D environment enabling user interaction through immersion (Bombari et al., 2015; Hu & Georgiev, 2020). VR experiences vary in form, including Immersive VR (IVR), VR-360, mobile VR, and Cave Automatic Virtual Environments (CAVEs), each with varying immersion and interactivity. IVR, the most widely recognized, uses HMDs with stereoscopic visuals, spatial audio, and motion tracking to create interactive environments. CAVE VR

projects virtual content onto walls, ceiling, and floor, enabling immersion without wearables. VR-360, while also using HMDs, primarily consists of pre-recorded spherical videos with limited interactivity, such as adjusting the viewing angle. A more basic variation, VR Cardboard, employs smartphones in inexpensive cardboard headsets, providing minimal immersion and interactivity at a lower cost. Beyond these technologies, it is noteworthy that some studies classify 2D screen-based environments as VR, despite lacking immersion. In immersion-critical domains like empathic design, these VR types are not interchangeable.

2.3. Empathic VR

VR's immersive simulations position it as a powerful tool for fostering empathy, with diverse disciplines tailoring their research approaches to align with their distinct perspectives and priorities.

In HCI and human factors, VR enhances designers' understanding of user experiences by immersing them in virtual environments that replicate real-world challenges, fostering deeper insight into user needs (Grech et al., 2024; Hu et al., 2021). In contrast, communication, media, and journalism leverage VR to advocate public awareness of humanitarian crises (Bujic et al., 2020; Herrera et al., 2018; Kors et al., 2016). Similarly, environmental and natural resource sciences use VR to simulate ecological impacts, cultivating environmental awareness and concerns (Calvi et al., 2018). Social science domains are also a major contributor to this field, with efforts to simulate social justice issues, including gender inequality, racial bias, and marginalization, school bullying and social exclusion (Gu et al., 2022; Kano & Morita, 2020; Muller et al., 2017). In healthcare, it serves both as a tool to enhance professionals' empathy toward patients and as a means to deepen their understanding of patient experiences. Meanwhile, psychology and education treat empathy as a skill that can be cultivated, using VR for structured empathy training (Barbot & Kaufman, 2020; Ventura et al., 2023).

While these diverse approaches harness VR's immersive potential to foster empathy, they vary in focus and impose distinct design requirements. Consequently, not all serve as proper references for the VR-based empathic design approach.

3. Conflicting implications for VR-based empathy design

Despite extensive research, applying VR-based empathy findings to design remains challenging due to ongoing debates on its implications. Disagreements persist over the scope of empathy VR can elicit, interpretations of its capabilities, its purpose in fostering empathy, key design dimensions, and implementation considerations.

3.1. Designing for which types of empathy?

A central debate is VR's ability to engage the full spectrum of empathic mechanisms (Figure 2). Martingano et al. (2021, 2023) found that VR primarily evokes affective empathy and compassion, with limited impact on perspective-taking or cognitive understanding. Conversely, other studies suggest VR can enhance both affective and cognitive empathy. Ventura et al. (2020) and Villalba et al. (2021) suggest VR enhances both affective and cognitive empathy, particularly perspective-taking. A systematic

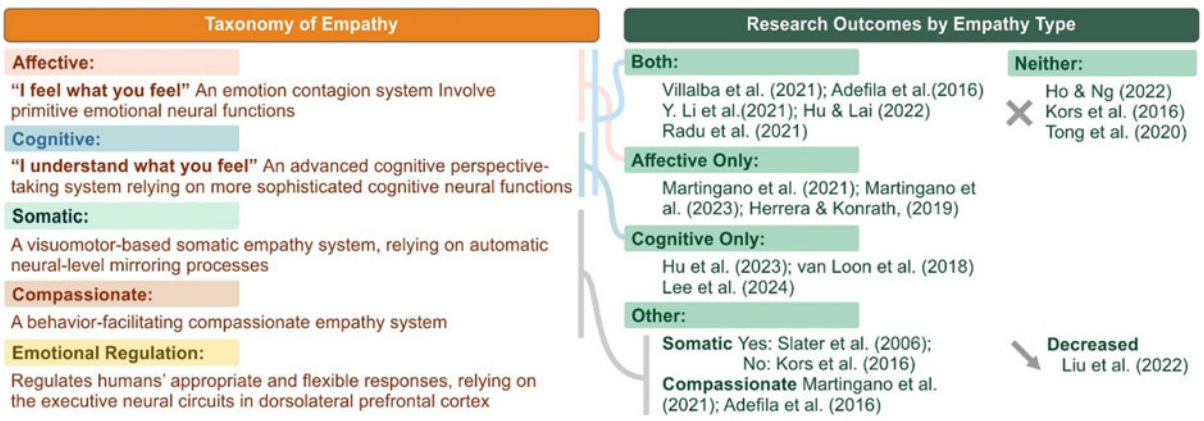

Figure 2. Types of empathy can VR elicit

review by Lee et al. (2024) further indicated that VR elicits both types of empathy, with cognitive empathy showing slightly stronger effects.
Further complicating the debate, some studies highlight discrepancies in measurement, suggesting VR enhances empathy-related understanding without corresponding changes in empathy scale assessments (Hu et al., 2023; Kors et al., 2016; Muller et al., 2017). Radu et al. (2021) reported increased empathy but a surprising decline in perspective-taking. Research on somatic responses is similarly inconclusive, with Hamilton-Giachritsis et al. (2018) and Slater et al. (2006) observing VR-induced effects, while Kors et al. (2016) found the opposite. Debates also persist over whether compassion is distinct from empathy (Cuff et al., 2016): few studies have explicitly explored VR's potential to increase compassion, though some report it as a byproduct of heightened affective empathy.
Collectively, this body of literature presents a fragmented and contradictory landscape, posing challenges for the design of effective empathic VR experiences.

3.2. What are the critical design dimensions?

Another key debate concerns the design dimensions essential for eliciting empathy in VR, particularly immersion, presence, theme, and interactivity. While immersion and presence are widely regarded as fundamental to effective VR experiences (Sundar et al., 2017), disagreements persist over their priority relative to thematic content and narrative.
For instance, Barbot and Kaufman (2020) identified sense of agency and virtual body ownership—both shaped by immersion and presence—as the strongest predictors of empathic change, with thematic content playing only a marginal role, prompting them to ask: "Does IVR media content truly matter?" Similarly, Hamilton-Giachritsis et al. (2018) questioned the impact of VR content, finding that participants' empathy increased regardless of whether they first encountered a positive or angry scenario.
In contrast, other studies emphasized the central role of narrative in shaping the experience. Shin (2018) argued that immersion is shaped by users' subjective interpretation of media stimuli rather than being an inherent feature of VR systems: participants adjusted their immersion based on how strongly the stimuli evoked intrinsic empathy. Supporting this view, Young et al. (2022) found that content and narrative delivery significantly influenced participants' attitudes. Furthermore, Han et al. (2022) found that while immersion enhanced presence, empathic reactions were ultimately determined by the type of perspective-taking employed.
The role of interactivity in empathic VR remains debated, with differing interpretations driving the divide. In some studies, interactivity refers to direct manipulation of elements within the virtual environment, such as touching, holding, or throwing virtual objects (Hu et al., 2023). In others, it is limited to vision-centric control, including adjustments to the field of view, gaze direction, and zoom capabilities (Bujic et al., 2020; Shin, 2018; Sundar et al., 2017). Given this discrepancy, it is unsurprising that some VR studies assert interactivity enhances empathy, while others disregard its significance. The remaining major dimensions do not involve substantial disagreement but rather suffer from a lack of sufficient attention to generate informed discussion.

3.3. What are the optimal design choices?

The lack of consensus on key design dimensions makes it difficult to isolate the impact of individual choices, thereby hindering the identification of optimal design strategies.
For instance, when focusing solely on thematic elements, one may find that the effectiveness of refugee life as a theme for empathic VR has been both supported (Bujic et al., 2020; Schutte & Stilinovic, 2017) and refuted (Kors et al., 2016) in different studies. Similar inconsistencies have emerged in the efficacy of themes such as school bullying (Gu et al., 2022; Liu et al., 2023), ocean protection (Blythe et al., 2021; Sundar et al., 2017), chronic illness (Hannans et al., 2021; Tong et al., 2020), colour vision deficiency (Ahn et al., 2013; Hu et al., 2023), and virtual character wellness (Ho & Ng, 2022; Slater et al., 2006).
Another key debate concerns the appropriate level of emotional intensity within empathic VR scenarios. Is it necessary for the theme to be intense and compassionate, or is everyday life sufficient (Hu et al., 2023)? In current practice, most empathic VR scenarios depict moderate to highly intense emotions, highlighting suffering (Schutte & Stilinovic, 2017), pain (Radu et al., 2021), or at least significant challenges (Hargrove et al., 2020). Emotionally neutral scenarios in empathic VR remain largely unexplored, partly because many empathic VR projects are designed with the primary goal of raising awareness about the well-being of underrepresented groups. Nevertheless, the limited studies

that have examined such approaches report significant improvements in empathy-related abilities, even in seemingly mundane experiences like feeding pigeons (Barbot & Kaufman, 2020). Further research is needed to determine whether neutral scenarios can offer a viable alternative for fostering empathy in VR.

Beyond these debates, several fundamental questions remain unanswered: To what extent should VR replicate reality? How explicitly must users empathize with virtual scenarios? How much background information should they receive? Which interaction tasks best elicit empathy? Addressing these questions is essential for advancing effective empathic VR design.

3.4. Is VR more effective than other media?

Given these debates, questions have emerged about whether VR is more effective than other media in eliciting empathy. The relative efficacy of VR in enhancing empathy remains inconclusive. Some studies support its significantly higher effectiveness (Bujic et al., 2020; Calvert & Abadia, 2020), attributing its advantages to VR's unique features, including its immersive environment, embodied engagement, sense of presence, and interactivity (Barbot & Kaufman, 2020; Villalba et al., 2021). In contrast, others report no significant difference between VR and lower-cost traditional media (Blythe et al., 2021) or even suggest that VR is less effective (McEvoy et al., 2016).

However, since VR's effectiveness is directly dependent on the design of both the virtual scenario and the experimental setup, direct comparisons between study outcomes may be of limited value. Developing clear guidelines for empathic VR design requires deeper analysis to understand these complex variables.

4. Parsing the complexity

To address inconsistencies in empathic VR research, this study examines how the literature conceptualizes empathy and VR, and related methodological choices. The analysis revealed several methodological mismatches that have evidently contributed to the observed discrepancies.

4.1. Fluidity of "enhancing empathy"

A key challenge arises from disciplinary differences in defining empathy, leading to varying expectations of what constitutes "enhanced empathy," which are often not explicitly articulated.

As previously mentioned, social sciences prioritize raising awareness of marginalized communities and societal issues, focusing on affective empathy to elicit compassionate responses (Bujic et al., 2020; Davis, 2019; Hargrove et al., 2020), with prosocial behaviours often regarded as evidence of enhanced empathy. In contrast, design, HCI, and education emphasize contextual understanding through simulated experiences (Grech et al., 2024; Hu et al., 2021), where perspective-taking and reducing biases are key indicators of enhanced empathy (Kano & Morita, 2020; Villalba et al., 2021) , while compassion is less central. Medical and healthcare fields take an intermediate approach, balancing both affective and cognitive aspects. Meanwhile, psychological research prioritizes enhancing one's inherent capacity for empathy rather than focusing on specific scenarios, emphasizing empathy as a trait rather than a transient state.

Given this complexity, the notion of "enhancing empathy" remains inherently fluid, as shown in Figure 3, with its precise meaning shifting across studies and domains (Lee et al., 2024; Ventura et al., 2023), suggesting that direct comparisons between these approaches may be inherently flawed.

4.2. Measurement concerns

A lack of awareness of paradigm differences has led to methodological concerns, particularly in measurement, with many studies adopting incompatible methods when referencing prior research.

Recent literature reviews indicate that psychological empathy scales—such as the Interpersonal Reactivity Index (IRI) and the Questionnaire of Cognitive and Affective Empathy (QCAE)—are the predominant tools for assessing empathy shifts before and after VR experiences (Lee et al., 2024). However, these scales assess dispositional empathy—an individual's stable capacity for empathy (Davis et al., 1996; Reniers et al., 2011), rather than transient fluctuations (Shen, 2010). While effective for tracking long-term changes through repeated training, they are ill-suited for measuring short-term shifts after a single VR exposure.

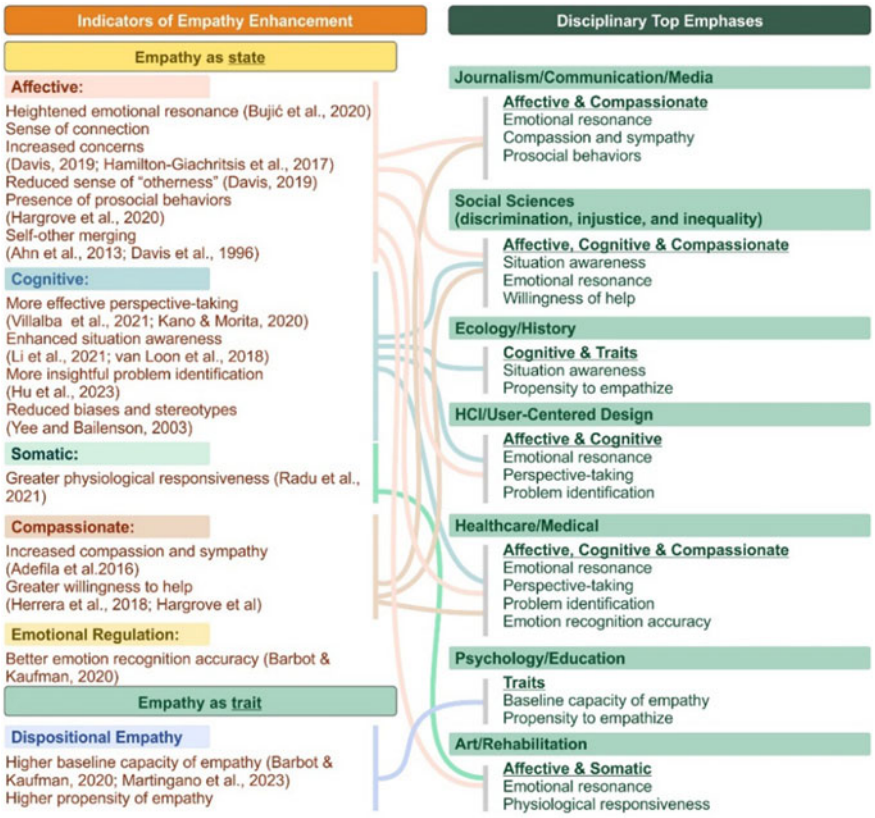

Figure 3. Different Interpretations of "Enhancing Empathy with VR"

Such methodological mismatches are widespread, with studies often attempting to measure dynamic changes in empathy using scales designed for trait-based assessment, as seen in Hu et al. (2023). In such cases, studies that document participants' positive reflections on their empathic experiences with VR yet fail to detect measurable changes (Hu et al., 2023; Kors et al., 2016; Muller et al., 2017) should reconsider whether their findings represent a true null result or if the measurement tools simply lacked the sensitivity to capture the changes.

4.3. VR type discrepancies

Confusions about VR types and their methodological implications present similar challenges. Different disciplines necessitate varying levels of interactivity for their empathic VR applications. Social science and communication research prioritize affective resonance through immersive, cinematic presentations, thus often treating immersive VR and VR-360 as functionally equivalent (Radu et al., 2021). Conversely, design and HCI fields prioritize interactivity and embodied experiences as essential VR components (Hu et al., 2021). The issue, once again, stems from insufficient clarification and awareness.

This absence of clear articulation has already led to confusion. For example, following the publication of contradictory reviews (Martingano et al., 2021; Ventura et al., 2020), the authors later collaborated to reconcile their findings and identified a key discrepancy: differences in inclusion criteria for VR types (Ventura et al., 2023). Ventura et al. (2020) focused exclusively on immersive VR, whereas Martingano et al. (2021) adopted a broader scope, incorporating VR-360 and other variations. Thus, without clearer distinctions, the field risks drawing misleading conclusions from studies that may not be directly comparable.

4.4. Unique concerns in empathic design practices

While recognizing these challenges clarifies inconsistencies in empathic VR research, it does not resolve the unique difficulties of applying VR in empathic design. On the one hand, while prior literature has highlighted uncertainties regarding empathy mechanisms, VR capabilities, and measurement approaches, there remains a lack of rigorous experimental validation to confirm these issues, leaving them an ambiguous area for design considerations. On the other hand, empathic design is inherently solution-driven.

The challenge, therefore, lies in designing VR experiences that generate insights applicable to real-world problem-solving rather than merely prioritizing emotional impact (Hu et al., 2021; Hu & Georgiev, 2020). While these studies offer valuable insights into the inconsistencies within this field, stronger empirical evidence is needed to translate findings into actionable design guidelines. Given the considerable divergences in design dimensions, direct comparisons across studies—without adequate experimental control—yield limited analytical value. Therefore, the next step in this research trajectory is to develop a systematically structured experiment that identifies the underlying factors contributing to these inconsistencies, providing a more stable foundation for analysis.

5. Next step: fixing the moving target

Resolving inconsistencies in empathic VR research requires rigorous experiments that directly address these variations. First, the VR scenario should apply established research insights to enhance its empathy-evoking potential, reducing the risk of design-related flaws. Next, carefully chosen measurement tools should be employed, using triangulation to assess whether discrepancies persist even in an optimized empathy-inducing scenario. This approach will help reveal the root causes of inconsistencies, offering clearer insights into contributing factors.

5.1. Intended VR design

Prior research suggests the following key design insights for effective empathic VR that will facilitate a methodologically controlled experiment.

- Themes: Healthcare- and medical-themed VR scenarios demonstrate the strongest impact on empathy, particularly those replicating bodily function symptoms from a first-person perspective (Barhoush et al., 2020; Trevena et al., 2024).
- Narrative: Narratives that portray a simulated individual's challenges with a negative emotional tone are most effective (Bujic et al., 2020; Hargrove et al., 2020; Lee et al., 2024; Radu et al., 2021). However, overly dramatic emotional arcs should be avoided, as they risk introducing the confounding influence of sympathy (Cuff et al., 2016).
- Story Perspective: First-person embodiment enhances immersion and emotional connection, whereas alternative viewpoints have shown weaker results (Ho & Ng, 2022; Kambe & Nakajima, 2022; van Loon et al., 2018).
- Interactivity Higher interactivity is considered a safer option as it enhances understanding by providing contextual and tacit knowledge (Hu & Georgiev, 2020), though its impact varies by domain (Bujic et al., 2020; Radu et al., 2021). Realistic interactive tasks that simulate user challenges through decision-making and operations are most effective (Banakou et al., 2013; van Loon et al., 2018).
- Level of Immersion: Across all VR types, HMD-based immersive VR is consistently more effective in enhancing empathic engagement (Lee et al., 2024).
- Environment: While VR design varies by theme and immersion, key factors remain consistent. Low visual realism does not reduce empathy (Kano & Morita, 2020), and non-interactive background elements support scenario comprehension, reinforcing ecological validity (Hu et al., 2023).
- Timeframe: Different types of empathy consolidate at varying rates, with emotions emerging instantly and understanding developing over time (Lee et al., 2024). To account for this, a two-stage study should include a consolidation period between the VR experience and reflection, potentially extending up to two weeks (Herrera et al., 2018).

5.2. Measurement matrix

Literature suggests combining psychological empathy scales, self-reflective interviews, and a mind-mapping techniques to assess participants' empathic experiences with VR. The logic is straightforward, as shown in Figure 4, if all results are negative, participants likely experienced no empathic response. This outcome would suggest either a fundamental flaw in the mechanism of empathic VR or inefficacies in the design of previous experiments. Conversely, if all measurements show positive results, it will confirm that prior VR development insights are effectively transferable to design practice and dispel concerns that empathy scales fail to capture state changes in empathy. Alternatively, self-reflection and

Assumptions Underlying Inconsistencies	Expected Enhancements from VR Experience?			
	Empathy Scale	Self-Reflection	Design Task	Mind Mapping
If inconsistencies are due to **Flawed Mechanism:**	NO No significant enhancement	NO No significant enhancement Potential overreporting due to social desirability	NO Vague and arbitrary problem definitions Superficial Problem Comprehension Limited Utility of Solutions	NO Random structure Inconsistent significance of factors Ambiguous descriptions
If inconsistencies are due to **Mismatched Methods:**	NO No significant enhancement	YES Significant enhancement	YES Concrete problem definitions Fact-based problem analysis Comprehensive solutions	YES Well-defined Structure Aligned significance of factors Clear descriptions
If inconsistencies are due to **Ineffective Design:**	YES Significant enhancement	YES Significant enhancement	YES Concrete problem definitions Fact-based problem analysis Comprehensive solutions	YES Well-defined Structure Aligned significance of factors Clear descriptions

Figure 4. Expected outcomes with different assumptions

mind-mapping may show positive outcomes even if the empathy scale detects no change. In this case, the results would validate concerns about methodological mismatches, demonstrating that traditional empathy scales may be inadequate for capturing the dynamic nature of empathy in VR experiences. Regarding measurement selection, the QCAE scale appears to be the most suitable choice for empathy assessment in this study, given its widespread use (Lee et al., 2024) and its notable association with mixed results (Hu et al., 2023). For naturalistic measurement, semi-structured interviews provide an effective approach to capturing participants' explicit reflections, offering a balance between structural rigor and flexibility to uncover deeper insights. Meanwhile, mind mapping should involve evaluating participants' perceptions of various design dimensions and identifying potential connections among them, providing a visual representation of their cognitive processing and empathic engagement.

6. Conclusion

This study examines the challenges of integrating VR-based empathy into design, where methodological inconsistencies have hindered its practical application. Our analysis identifies key factors contributing to these inconsistencies, including methodological limitations, design variability, and conceptual ambiguity. To address these issues, we propose a controlled experimental framework incorporating optimized VR scenarios, empathy scales, semi-structured interviews, design ideation tasks, and mind mapping. Refining these methodological approaches will help researchers and designers better harness VR's potential to foster empathy in design and beyond. By bridging theoretical insights with practical design strategies, this study lays the ground for a more cohesive approach to empathic VR research—one that balances immersive storytelling with methodological rigor to drive meaningful design outcomes.

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