Virtuality Does Not Exist: Perception at the Endpoint of VR

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Abstract: The idea of complete virtuality has accompanied virtual reality research since its beginnings. It appears as an implicit boundary concept in visionary ideas such as Sutherland's Ultimate Display as well as in formal classifications, particularly in Milgram and Kishino's reality-virtuality continuum. At the same time, for over three decades there has been broad, interdisciplinary criticism that questions this assumption from very different theoretical perspectives. This text reconstructs this landscape and shows that, despite its heterogeneity, it repeatedly encounters the same structural limit: inherent incompleteness of the perceptual mediation. On this basis, we use an event field theory as a transfer function of perception to describe the technologically feasible state space with transformable dimensions. It is shown that a state of complete virtuality cannot be defined under these conditions. Virtual reality is thus not an approximation of an endpoint, but merely a specific configuration within the space of perception. The real question, therefore, is whether the concept of a completely virtual perception endpoint can be defined conclusively at all. The article argues that virtuality is not an unattainable limit of immersive technology, but rather an insufficiently defined concept within the structurally constrained space of mediated perception.

Keywords: Virtual Reality, Perception, Interaction, Mixed Reality, Presence, Perceptual Mediation, PHANTOMATRIX.

1. INTRODUCTION

Since the 1960s, virtual reality has been discussed not only as a technical development, but also as a frontier concept. This often refers to a state in which perception is completely determined by technically generated stimuli and physical reality loses its reference function. This assumption is rarely formulated explicitly but is deeply anchored in the language of the field. Terms such as cyberspace, fully virtual environment, complete immersion, or total virtuality implicitly assume that reality is fundamentally replaceable. It is noteworthy that this assumption rarely becomes the subject of systematic analysis itself. Instead, it is carried along in visions, classifications, and metaphors. Two works continue to structure this concept to this day. Ivan Sutherland's The Ultimate Display (Sutherland IE, 1965) and Paul Milgram's Reality-Virtuality Continuum (Milgram et al., 1995; Milgram et al., 1994). These texts are nuanced, explicitly multimodal, and methodologically reflective. Precisely for this reason, they are not suitable as definitive conclusions, but rather as serious starting points.

The implicit assumption of complete virtuality is not a single theorem, but a latent structural motif. It always occurs when virtual reality is understood as the antithesis of reality. In this logic, reality is completely given, virtuality is completely constructed, and between the two lies a transitional area. This structure is attractive because it promises simplicity. It allows progress to be thought of as movement along a scale. More immersion, more fidelity - more virtuality. However, this concept has long been under pressure not from a single direction, but from many.

Our text does not pursue any historical or normative goal. It does not ask how good today's VR systems are or could be, but rather whether the boundary concept they implicitly aim for can ever be achieved. This question cannot be answered technologically, but only structurally. To make the endpoint assumption explicit, our PHANTOMATRIX framework is used here. It models XR as a chain of transfer functions between event and phantom fields, allowing the concept of “complete virtuality” to be tested for definability at the level of the secondary event field.

2. THE CRITICAL LANDSCAPE: INDEPENDENT LINES, SAME BOUNDARY

We will now attempt to reconstruct the most important lines of criticism without attempting to evaluate them. The initial goal is to make them fully visible.

Telepresence: Perception as Action-Bound Feedback

The early days of virtual reality research were particularly influenced by NASA and VPL actors through their work on telepresence. Thomas B. Sheridan understands perception not as stimulus reception, but as action-bound feedback. In an early article, Sheridan defines presence as the extent to

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which an actor can act effectively while perception and action remain temporally and physically coupled (Sheridan TB, 1992). He defines the point of perfect presence as that at which the extent of sensory information, control of the relationship of sensors to the environment, and ability to modify the physical environment are maximal. Sheridan admits that we have relatively limited understanding about human control loops. He later clarifies that even highly mediated systems do not eliminate the coupling of action and perception, and he makes it clear that presence encompasses all salient senses (Sheridan TB, 1996). He recognizes an evolutionary asymmetry between Darwinian and technological evolution, since Darwinian evolution first developed the senses of force and kinesthetic feedback, then sound and vision. His assessment that there is no satisfactory solution for tactile displays in virtual space is still valid even after three decades. Thus, perfect tele- or virtual presence is no longer just maximum immersion, but the functional indistinguishability in action. Sheridan thus systematically opens up the space of perception (modally, dynamically, action-related) without closing it ontologically.

Draper, Kaber, and Usher take a significantly different position in the telepresence debate. In their Speculations on the Value of Telepresence (Draper et al., 1999), the authors do not expand on Sheridan's operational framework, but instead subject the prevailing telepresence paradigm itself to critical examination. Their central concern is not whether telepresence can be achieved, but whether it should even be a general design goal. They question the assumption that immersive interfaces and faithful reproduction of a remote environment necessarily lead to superior human-machine interaction. In their paper, they adopt the prevailing definition of immersion as multimodal sensory control (Biocca and Levy, 1995) only to decouple it from performance and to question its status as a general design objective. They argue that the widespread equation of telepresence with effectiveness reflects a technology-driven rather than an empirically grounded design philosophy. According to their analysis, the pursuit of maximum immersion runs the risk of becoming an end in itself, detached from task performance and situational requirements.

Presence Research: Sensorimotor Contingency Instead of Sensory Substitution

Presence research, significantly influenced by Mel Slater, consistently distinguishes between technical immersion and experienced presence. Slater's argument is formulated explicitly in response to the Presence Questionnaire (Slater M, 1999), proposed by Witmer and Singer, which operationalizes presence by aggregating presumed system and user factors (Witmer and Singer, 1998). Slater insists on separating measurable system immersion from subjective response and questions the assumption that increased sensory fidelity or immersive system properties alone can account for experienced presence. In a later publication together with Sanchez-Vives, they show that presence and body-related illusions depend on the successful substitution of real sensory input by computer-generated stimuli in a way that preserves coherent sensorimotor coupling (Sanchez-Vives and Slater, 2005). Inconsistencies between bodily action, proprioception and sensory feedback can lead to breaks in presence or discomfort, whereas visual realism alone is insufficient to account for the observed behavioral and physiological responses. These results strongly indicate that virtual environments do not support the notion of an autonomous perceptual reality but remain dependent on bodily coherence and physical reference. A few years later, Slater reframes presence as a conditional perceptual phenomenon rather than a function of sensory completeness (Slater M, 2009). He distinguishes immersion as a physical system property from presence as an experiential effect that arises when sensorimotor contingencies are sufficiently coherent. Place Illusion describes the experience of being located in a place despite knowing it is artificially generated, while Plausibility concerns whether events are perceived as actually happening to the participant. Both can occur under reduced sensory fidelity, provided that action-perception coupling remains stable and predictable. Immersion therefore defines boundary conditions, not a scalable endpoint. Presence emerges as a contingent, system-bound state rather than a cumulative result of increasing sensory control.

Interaction Beyond Representation

Dourish argues in human computer interaction that treating context as representable information is a category error. Contextuality is relational, occasioned, and produced in the course of activity; context and action are mutually constitutive rather than separable (Dourish P, 2004). He further clarifies that "embodiment" is not defined by physical reality per se, but by availability for engagement.

In the mixed-reality discourse, the assumption of a linear progression toward a fully virtual endpoint is

explicitly abandoned. Benford and colleagues propose a classification of shared spatial systems along the orthogonal dimensions of transportation, artificiality, and spatiality. Rather than positioning systems on a single reality-virtuality axis, their framework describes how physical and synthetic elements are combined in different relational configurations (Benford et al., 1996). Mixed reality is introduced not as an intermediate step toward full virtuality, but as a design space in its own right, characterized by hybrid arrangements across these dimensions. This does not privilege the extremes of complete physicality or total synthesis as goals. Instead, it identifies hybrid configurations as the most productive direction for future systems.

In their comprehensive survey, Billinghurst *et al*. treat augmented and mixed reality as independent technological and design spaces rather than as transitional stages toward full virtual reality. While the Mixed Reality continuum is discussed as a descriptive taxonomy, it is not used to imply a developmental trajectory. Instead, AR, MR, and VR are characterized by distinct goals, constraints, and evaluation criteria (Billinghurst et al., 2015). Virtual reality does not function as a normative endpoint in this framework. The survey consistently frames AR systems in terms of how digital content is integrated into embodied action within the physical world, thereby rendering the notion of a fully virtual endpoint practically irrelevant rather than theoretically contested.

The most explicit criticism is expressed by Skarbez, Smith, and Whitton. In revisiting Milgram and Kishino's Reality-Virtuality Continuum, they argue explicitly that the continuum is discontinuous and that the virtual reality endpoint is unreachable (Skarbez et al., 2021). Their argument does not concern technological limitations, but structural constraints of perception. Even an idealized Ultimate Display capable of fully controlling exteroceptive sensory input would still constitute mixed reality, as interoceptive senses such as proprioception and vestibular perception remain coupled to the physical body. As a result, conventional virtual environments, or what the authors term external virtual environments, cannot form an autonomous perceptual reality. Only a hypothetical "Matrix-like" system involving direct brain stimulation could lie outside the mixed reality spectrum. This position is consistent with philosophical accounts of virtuality as symbolic or dependent reality (Chalmers and Peacock, 2022; Heim M, 1993).

The approaches mentioned differ in their theoretical starting points and methodological focuses. Nevertheless, they arrive at the same conclusion. Mediated perception does not define a terminal perceptual state.

3. FROM CONVERGING LIMITS TO A FORMAL MODEL

Across presence research, embodied interaction, mixed reality, and explicit endpoint critiques, a common pattern emerges. Virtual experience remains partial, relational, and resistant to closure. These limitations are repeatedly described, yet they are treated as contingent - attributed to incomplete technology, insufficient immersion, or unresolved design challenges. The convergence of independent critiques suggests a different explanation. The failure does not arise from insufficient approximation of reality, but from a mischaracterization of the space in which virtuality is assumed to operate. Perception is not a set of channels to be exhaustively replaced, but a structured, embodied process in which only certain dimensions are transformable, while others are not. As a consequence, virtual systems do not progress toward a stable endpoint. Instead, they encounter the same structural boundary across different implementations and theories.

Our original PHANTOMATRIX formulation implicitly assumes that perceptual access to events is fully mediated (Grasnick A, 2023). This assumption requires refinement. While all experiential interpretation may involve mediation, not all perceptual dimensions are equally subject to transformation within a mediating chain. Some dimensions remain effectively invariant under mediation, either because they cannot be transformed without losing their functional role, or because they are only weakly or indirectly mediable at all (e.g., gravity, metabolic states). This asymmetry can be observed in current VR systems, where visual perspective and scene geometry can be extensively transformed, while vestibular orientation and bodily balance remain physically anchored. For both reasons, these dimensions prevent perceptual closure even under idealized conditions.

The clarification above sharpens the problem without altering its structure. All perceptual access remains mediated; however, mediation does not act uniformly across perceptual dimensions. The absence of a virtual endpoint thus follows from internal asymmetry, not from missing mediation. PHANTOMATRIX formalizes this asymmetry by treating perception as a structured state space in which

transformations operate under constraints. Instead of assuming that all perceptual dimensions can be arbitrarily modified, the model distinguishes between dimensions that admit controlled transformation and those that function as structural invariants. Crucially, these invariants are not external to the perceptual process; they persist within mediation and limit its expressive power. From this perspective, virtual environments do not fail to achieve closure because they are incomplete simulations. They fail because a terminal condition would require all perceptual dimensions to be jointly transformable, which the structure of perception itself does not permit. The virtual endpoint is therefore not unreachable in practice, but undefined within the space of admissible transformations.

Perceptual State Space and Constrained Transformations

PHANTOMATRIX models mediated access to events as a structured state space rather than as a channel bundle or representational pipeline. It does not model perception, presence, or embodiment, but the mediating structures that precede perceptual experience. Let E_1 denote the primary event field in the physical world and E_2 the secondary event field generated by technical mediation, in which the observer remains embedded. Mediation reorganizes relations within the event field rather than separating observer and world. The observer constitutes a shared reference across E_1 and E_2. Perception unfolds only after this mediation, through a sequence of non-invertible transformations,

$$E_1 \xrightarrow{F_1} \xrightarrow{F_2} E_2$$

Where E_1 and E_2 denote primary and secondary event fields, F_1 and F_2 intermediate phantom fields, and the arrows indicate directed, non-invertible transfer operations. Each transformation reduces or re-encodes aspects of the originating event.

Crucially, the transformation operators do not act uniformly across perceptual dimensions. The perceptual state space is partitioned into dimensions that admit controlled transformation and dimensions that do not. Some dimensions are transformable within mediation (e.g., visual perspective, auditory spatialization), while others are effectively invariant under transformation (e.g., vestibular orientation, bodily balance). Invariance may arise either because a dimension cannot be transformed without losing its functional role, or because it is only weakly or indirectly mediable at all.

PHANTOMATRIX remains agnostic as to whether such dimensions constitute a strict bypass of mediation or an internal limit of transformability. This distinction is not required for the central result. In both cases, the perceptual state space lacks the degrees of freedom necessary for total closure. No sequence of transformations can jointly control all dimensions of perception. From this formal perspective, virtual environments do not fail because mediation is incomplete, but because mediation is structurally constrained. A fully virtual endpoint would require all perceptual dimensions to be jointly transformable within the mediating chain. Since this condition is not satisfied, the endpoint is is undefined within the admissible transformation space. This framework is not intended as an implementation model. However, it can be operationalized by treating perceptual dimensions as variables and examining which dimensions within a given XR system allow for controlled transformation and which remain unchanged.

At this point, the problem can be stated without qualification. What repeatedly fails across the examined accounts is not virtual reality as a technological practice, but the notion of virtuality as a perceptual endpoint. The idea that perception could converge toward a fully virtual state detached from bodily, contextual, and physical reference finds no support in perception research, human-computer interaction, mixed reality frameworks, or explicit endpoint critiques. Virtuality, understood in this sense, does not exist.

This result is directly related to a widespread but rarely explicitly stated assumption in the development of immersive media, namely that progress consists in approaching an implicit notion of maximal virtuality. The analysis above indicates that this assumption is not only hardly possible to achieve, but effectively out of reach. Recent XR research conceptualizes immersion and presence as graded dimensions whose levels can be increased through system properties and content design. As exemplified by unified models of immersive experience, progress is evaluated in terms of higher degrees of immersion rather than with respect to a formally defined perceptual endpoint (Lee H, 2025). If no endpoint of perception can be defined, “more virtuality” cannot serve as a meaningful criterion for design or evaluation. Nevertheless, contemporary VR research routinely evaluates immersive systems using

graded measures of presence, immersion, and user experience, treating progress as improvement along these dimensions without reference to any terminal condition (Bareišytė et al., 2024). Even if no explicit endpoint is claimed, the use of graded evaluation criteria presupposes a notion of improvement whose limiting condition remains unexamined.

4. CONCLUSION

This paper set out to examine why virtual reality, despite decades of technical progress and theoretical refinement, persistently fails to converge toward a stable endpoint. Across presence research, embodied interaction, mixed reality frameworks, explicit endpoint critiques, and media philosophy, a consistent pattern emerges: virtual experience remains partial, relational, and structurally dependent on embodied conditions.

PHANTOMATRIX provides a unifying explanation for this convergence. By modeling perception as a constrained state space of mediated transformations, it becomes clear that virtuality is not limited by insufficient fidelity or incomplete multisensory substitution. Rather, it is bounded by structural asymmetries within perception itself. Some perceptual dimensions admit transformation, others remain invariant or only weakly mediable. Whether these limits are understood as internal invariances or as effective bypasses of mediation is secondary; in both cases, they prevent a virtual endpoint. As a result, the notion of a fully autonomous virtual reality is not merely technologically unattainable, but conceptually problematic. Virtuality does not fail to reach completion - it lacks a coherent condition of completion. What exists instead are mediated experiential configurations that remain necessarily entangled with bodily, contextual, and physical reference.

In this sense, virtuality does not exist as an endpoint. It exists only as a mode of transformation within perception - powerful, generative, and real in its effects, but structurally incapable of becoming total.

The rejection of a virtual endpoint has direct implications for the research, design, and evaluation of immersive media. Treating maximum immersion as a target state presupposes an idea of completion that this analysis declines to accept. This avoids the vaguely defined task of optimizing individual sensory channels toward an imagined condition of complete immersion. Instead, the relevant question becomes how mediation is structured and what forms of experience it enables under given conditions.

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Received on 21-11-2025 Accepted on 20-12-2025 Published on 29-12-2025

https://doi.org/10.65638/2978-8811.2025.01.08