

# TELEPRESENCE

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## 1. Definition and Foundational Concepts

Telepresence, in its most fundamental definition, refers to the subjective psychological experience of being physically present in a location other than one's current physical location, achieved through technological mediation. This feeling is triggered when an individual receives high-fidelity sensory input--visual, auditory, haptic, or even olfactory--that originates from a distant or simulated environment. It is far more than simply observing a scene; it involves a profound cognitive shift where the brain accepts the mediated environment as the primary reality, leading to genuine behavioral and emotional responses appropriate to that distant locale. The core concept hinges on the perceptual system's ability to override the awareness of the mediating technology, thereby blurring the line between the physical self and the projected self. Historically, the term was coined in the 1980s, primarily in the context of advanced robotics and remote manipulation, emphasizing the operator's feeling of being situated within the robot's environment, but its scope has dramatically expanded to encompass virtual reality (VR), augmented reality (AR), and advanced cinematic experiences. The feeling of **telepresence** is thus a powerful demonstration of the plasticity of human perception and the brain's willingness to integrate external sensory data into the body schema.

The experience of telepresence is intrinsically linked to the concept of "presence," which is defined as the normal, non-mediated feeling of being situated in one's immediate physical surroundings. Telepresence is, therefore, a specific form of presence--a "mediated presence." This psychological phenomenon requires a successful decoupling of the physical body from the perceived environment. When telepresence is achieved, the user's attention, cognitive resources, and emotional investment are directed toward the remote location, diminishing the salience of the immediate physical surroundings. This successful integration requires the technological interface to provide sensory data that is sufficiently coherent and compelling to create what is often termed a "suspension of disbelief," where the individual reacts instinctively to events within the simulated space, such as ducking when an object appears to fly past or experiencing vertigo when standing near a virtual edge. Achieving a high degree of telepresence is the ultimate goal of many immersive technologies, as it directly correlates with the effectiveness and psychological impact of the mediated experience.

Crucially, telepresence involves a complex interplay between sensory input and cognitive processing. It is not merely about the quality of the visual display; rather, it depends heavily on spatial coherence, temporal synchronization (low latency), and the congruence across multiple sensory modalities. For instance, if visual input suggests movement but auditory input is delayed or inconsistent, the sense of telepresence is rapidly diminished, often leading to simulator sickness or cybersickness. The feeling is subjective and varies greatly among individuals, but researchers typically measure it using self-report questionnaires that assess factors like spatial orientation (feeling of being "there"), involvement (degree of focus on the mediated environment), and

experienced realism (the authenticity of the sensory data). Understanding these foundational concepts is essential for designing effective systems, whether for remote surgery, educational simulations, or entertainment, where the psychological acceptance of the mediated environment dictates the success of the interaction.

## 2. Psychological Mechanisms of Telepresence

The psychological mechanisms underlying telepresence involve several core cognitive processes, primarily focused on spatial awareness, body representation, and attentional focus. One primary mechanism is the sensory dominance hierarchy, where the brain prioritizes certain sensory inputs, often sight and sound, to construct a model of reality. When technologically mediated sensory data is presented with extremely low latency and high consistency, the brain attributes the source of this data to the virtual or remote location, effectively overwriting the input received from the immediate physical environment. This process requires significant cognitive resources devoted to integrating the mediated sensory stream, leading to a state of high absorption. Furthermore, the feeling of agency--the ability to act upon and influence the remote environment--is critical. If a user's actions (e.g., turning their head, moving their hand) are immediately and accurately reflected in the distant locale, the feedback loop reinforces the sense of being present and acting within that space.

Another key psychological factor is the concept of "Plausibility Illusion" and "Place Illusion." The Place Illusion refers to the strong subjective feeling of being in the simulated or remote location, driven largely by high sensory fidelity and field of view. The Plausibility Illusion, however, relates to the acceptance of the events occurring within that mediated environment as real or plausible, even if the user knows rationally that the environment is artificial. This cognitive acceptance is vital because it allows for genuine emotional and physiological responses, such as fear, excitement, or anxiety, which are integral to a complete telepresent experience. For example, a user in a virtual reality experience might consciously know they are safe in a laboratory, yet their heart rate increases and they exhibit a fear response when encountering a virtual threat, demonstrating the successful achievement of **telepresence** and the subsequent psychological immersion.

The embodiment transfer mechanism is also central to telepresence, especially in systems involving avatars or remote robots. When a user controls a surrogate body (virtual or physical) and receives sensory feedback aligned with that body's perspective, the brain often incorporates the surrogate body into the user's self-representation (body schema). Research has shown that users can experience ownership over a virtual body, feeling touches applied to the avatar or even reacting physically to perceived threats to the avatar. This feeling of embodiment profoundly enhances telepresence, making the interaction feel more direct and less mediated. The success of this embodiment relies heavily on visuomotor synchronization; if the visual feedback of the avatar's actions perfectly matches the user's proprioceptive sense of movement, the illusion of being the avatar, or being present where the avatar is, is solidified.

### 3. The Role of Sensory Fidelity and Immersion

Sensory fidelity stands as a cornerstone for achieving high levels of telepresence. Fidelity refers to the accuracy and resolution with which the sensory data from the remote or virtual environment is captured and presented to the user. Low fidelity--blurry images, low frame rates, compressed audio, or noticeable lag--acts as a constant psychological reminder of the mediation technology, shattering the illusion of presence. Conversely, high fidelity, characterized by wide fields of view, stereoscopic 3D rendering, high spatial audio resolution, and realistic haptic feedback, minimizes the cognitive load required to interpret the sensory input, making the integration of the mediated environment seamless. The goal is to maximize the bandwidth of sensory data transmission while minimizing system latency, ensuring that the user's perception of reality is dominated by the synthetic input.

Immersion, often confused with telepresence, is a distinct but related concept that primarily describes the objective capabilities of the technological system itself. A highly immersive system is one that encompasses the user's sensory channels fully, isolating them from the real world. For instance, a head-mounted display (HMD) offers a high degree of immersion because it blocks out peripheral vision and ambient sounds, thereby increasing the potential for **telepresence**. However, high immersion does not guarantee telepresence; a highly immersive but poorly designed system (e.g., one with poor tracking or high latency) may still fail to induce the subjective feeling of being "there." Therefore, immersion is the necessary technological precursor, setting the stage, while telepresence is the resulting subjective psychological outcome realized by the user.

The synchronization across various sensory modalities is perhaps more crucial than the raw resolution of any single sense. Human perception is highly sensitive to cross-modal inconsistencies. If a user sees a virtual object collide but hears the corresponding sound a fraction of a second later, or if the visual perspective shifts without the appropriate vestibular (balance) cues, the brain detects these discrepancies, leading to a breakdown in the sense of presence. Researchers emphasize the importance of achieving "sensory congruence," where all inputs--visual, auditory, and haptic--are perfectly aligned in space and time relative to the user's perceived location and actions. When this congruence is achieved, the brain naturally accepts the mediated environment, allowing for deep cognitive absorption and the robust manifestation of telepresence.

### 4. Technological Drivers of Telepresence

The technological realization of telepresence is driven by several convergent fields, most notably advanced computing power, high-resolution display technologies, and sophisticated sensor arrays. Modern Graphics Processing Units (GPUs) are essential for rendering complex virtual environments at the high frame rates necessary to minimize motion blur and ensure visual stability, a key requirement for maintaining the illusion of presence. Display technologies, including 4K and

8K resolutions in HMDs and large projection systems, increase pixel density, making the mediated environment appear more realistic and reducing the visibility of the screen door effect, which detracts from the sense of being present. The continuous advancement in wide Field-of-View (FoV) optics is also critical, as mirroring the natural peripheral vision significantly enhances the user's spatial awareness and feeling of being enveloped by the environment.

Low latency tracking and communication systems represent another indispensable technological driver. Latency, the delay between a user's action (e.g., turning their head) and the system's response (updating the visual display), is the primary enemy of telepresence. Even delays measured in tens of milliseconds can disrupt the visuomotor coordination loop, leading to simulator sickness and immediate loss of the feeling of presence. Therefore, sophisticated tracking systems--utilizing technologies like inside-out tracking, external base stations, and robust inertial measurement units (IMUs)--must capture movement with microsecond precision. Furthermore, in systems involving remote operations (e.g., remotely controlling a robot on Mars), maintaining high-speed, reliable communication links is paramount, often requiring complex network protocols and predictive modeling to compensate for unavoidable physical distance delays.

Beyond visual and tracking systems, the incorporation of high-fidelity auditory and haptic feedback loops dramatically elevates the potential for strong **telepresence**. Spatial audio, which accurately simulates the direction and distance of sounds in a 3D space, anchors the user within the environment and provides crucial non-visual cues. Haptic devices, ranging from simple vibration controllers to complex exoskeletons and force-feedback systems, allow the user to interact physically with the remote or virtual environment, providing the necessary tactile validation that their actions have real consequences in that space. The successful integration of these technologies creates a holistic sensory experience, making the mediated environment feel tangible and responsive, thus solidifying the psychological acceptance of the distant location as the current reality.

## 5. Distinctions: Presence, Immersion, and Telepresence

Although often used interchangeably in casual discussion, "presence," "immersion," and "telepresence" are technically distinct concepts critical to psychological research in mediated realities. As established, **presence** is the fundamental, non-mediated psychological state of being situated in one's immediate physical surroundings. It is the baseline human experience. Immersion, conversely, is an objective, measurable property of the technological system itself--it describes the extent to which the technology manages to create a comprehensive, believable, and enveloping experience for the user, typically quantified by factors such as display resolution, field of view, degrees of freedom in tracking, and audio isolation. A CAVE (Cave Automatic Virtual Environment) system, which projects visuals onto all walls and the floor, is highly immersive.

Telepresence, unlike the objective measure of immersion, is the subjective psychological outcome. It is the feeling of "being there" that results when a user interacts with a highly immersive system. It is a state achieved when the brain successfully substitutes the mediated environment for the physical one. This distinction is vital for researchers: one can objectively measure the system's immersion (e.g., its hardware specifications), but one must subjectively measure telepresence (e.g., through user self-reports and physiological responses). A system can be technologically immersive but fail to induce telepresence if the content is poorly designed or if there is excessive lag. Conversely, a less immersive system might still evoke moments of telepresence if the content is highly engaging and emotionally resonant.

The related concept of "cybersickness" further illuminates these distinctions. Cybersickness, similar to motion sickness, arises when there is a conflict between the visual input (which suggests motion or spatial changes) and the vestibular and proprioceptive inputs (which indicate the body is stationary or moving differently). This sensory mismatch immediately destroys the feeling of telepresence because the cognitive system detects the artificiality of the experience. Thus, while high immersion sets the stage by maximizing sensory input, it is the successful coherence and synchronization of that input--preventing sensory conflict--that ultimately determines whether the subjective state of **telepresence** is attained and sustained.

## 6. Applications in Therapy and Training

The successful induction of strong telepresence has opened up powerful new avenues for psychological therapy and specialized professional training. In therapeutic settings, virtual reality environments leverage telepresence to create controlled, yet highly realistic, exposure scenarios for treating anxiety disorders, particularly phobias (e.g., fear of heights, spiders, or public speaking) and Post-Traumatic Stress Disorder (PTSD). By placing the patient in a compelling virtual environment where the sense of presence is strong, therapists can gradually expose them to triggering stimuli, allowing them to process fear responses in a safe, repeatable, and scalable manner. The effectiveness relies directly on the degree of telepresence achieved; if the environment feels real, the fear response is genuine, leading to more successful cognitive restructuring and desensitization than traditional imagery-based techniques.

In professional training and simulation, telepresence allows individuals to gain complex, high-stakes experience without real-world risk. Fields such as medicine, aviation, military operations, and remote industrial maintenance heavily rely on simulations powered by advanced telepresence systems. For surgeons, VR allows practice of intricate procedures, honing motor skills and decision-making under realistic pressure, where the feeling of being present in the operating theater is essential for skill transfer. Similarly, military and law enforcement training uses immersive scenarios to develop tactical responses and stress inoculation. The fidelity of the experience--the feeling that one is truly there and that the consequences are real--is what drives effective learning

and muscle memory formation, demonstrating the practical value of a robust sense of **telepresence**.

Furthermore, telepresence facilitates remote collaboration and education. In remote education, students can take virtual field trips to inaccessible locations or participate in simulated laboratory experiments that would be too costly or dangerous in the real world. For collaborative engineering or design, shared telepresent environments allow geographically dispersed teams to interact with 3D models and prototypes as if they were physically standing together around the object. These applications underscore the transformative potential of telepresence, not just as a fascinating psychological state, but as a critical tool for knowledge acquisition, skill refinement, and emotional regulation across diverse professional domains.

## 7. Ethical and Social Implications

As telepresence technologies become more ubiquitous and sophisticated, they raise significant ethical and social questions concerning identity, reality perception, and interpersonal relationships. One primary concern relates to the blurring of the line between mediated and actual reality. If simulated environments can induce profound psychological and emotional responses, there is a risk that individuals may struggle to differentiate between virtual and real experiences, potentially leading to dissociative states or an avoidance of real-world interactions in favor of more controllable and gratifying virtual ones. The psychological impact of experiencing virtual harm or trauma while in a strong state of telepresence also warrants careful ethical consideration, particularly regarding the long-term emotional residue.

Socially, advanced telepresence alters the nature of human interaction. While it enables powerful remote collaboration, it also introduces challenges regarding authenticity and accountability. When individuals interact through avatars in telepresent environments, questions arise about the ethical boundaries of behavior and the consequences of actions taken by a virtual self. Furthermore, the pervasive capture and use of sensory data necessary to create compelling telepresence experiences raise serious privacy concerns. The level of detail required--from eye-tracking data to physiological responses--creates an unprecedented stream of personal information that must be protected and regulated to prevent misuse or manipulation.

Finally, there is the ethical dilemma concerning access and equity. High-fidelity telepresence technology currently remains expensive, potentially creating a "presence gap" where access to enhanced educational, therapeutic, and professional opportunities is restricted to those with the necessary resources. Ensuring equitable access to these powerful tools is a crucial social responsibility. Researchers and developers must adhere to strict ethical guidelines regarding content creation, data handling, and the psychological safeguarding of users, particularly minimizing the potential for addiction or psychological distress resulting from prolonged or intense

states of **telepresence**.

## 8. Future Directions in Telepresence Research

Future research in telepresence is focused intensely on integrating advanced neurotechnology and refining sensory feedback loops to achieve unprecedented levels of realism and control. One major direction involves Brain-Computer Interfaces (BCIs), which aim to allow users to control remote systems or avatars directly through neural activity, bypassing traditional physical controllers entirely. This level of direct mental control would dramatically enhance the feeling of agency and embodiment, pushing telepresence closer to a truly seamless cognitive experience. Furthermore, integrating physiological monitoring (e.g., heart rate, galvanic skin response) into telepresence systems will allow for adaptive environments that react in real-time to the user's emotional state, further solidifying the sense of authenticity.

Another critical area of development is the expansion beyond visual and auditory input to include the "chemosensory" modalities: smell and taste. While technically challenging, integrating realistic olfactory and gustatory feedback would significantly increase the overall sensory congruence, making virtual or remote environments indistinguishable from reality for the brain. Imagine a remote surgical environment where the user can smell cauterization, or a training simulation where the user can taste contaminants--such additions would dramatically enhance the psychological fidelity and practical utility of telepresent systems. Research into advanced haptic gloves and full-body suits is also progressing rapidly, moving beyond simple vibrations to render complex textures, temperatures, and resistance forces, allowing for true physical interaction with the mediated space.

Ultimately, the future of telepresence involves creating persistent, interconnected virtual environments--often referred to as the metaverse--where individuals can maintain a continuous sense of presence regardless of their physical location or time of day. Research must shift toward understanding the long-term cognitive and social impacts of living and working in these spaces, including how chronic telepresence affects memory formation, attention span, and social behavior. The ultimate goal is to achieve "Turing-level telepresence," a hypothetical state where a user cannot distinguish the mediated environment from the actual physical world, demonstrating the complete success of technological mediation in overriding primary reality perception and ushering in a new era of human-computer interaction defined by profound **telepresence**.