

Dimensions of Immersive Auditory Experience

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Introduction

The term “Immersive” is used everywhere.

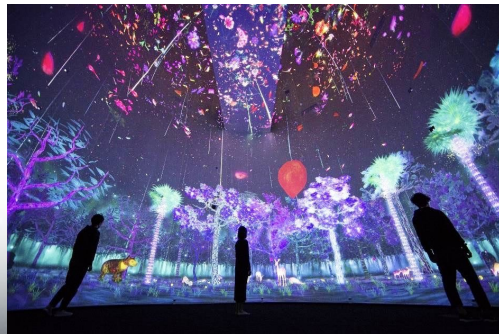
Immersive audio



Immersive games



Immersive art installation



Immersive theatre



Introduction

- How can we make our content more immersive?
- But first, what does “Immersive” mean exactly?



Immersive?



Immersive?

Introduction

- There is no clear consensus on what immersion means yet.
 - It is not a simple concept.
- Potential confusion due to many associated terms and concepts.
 - Different terms with a similar meaning or the same term with different meanings.
 - Inconsistency in the literature.

Today's talk

- To discuss the multidimensionality of immersion.
- To propose a standard terminology to avoid unnecessary confusion.
- To propose a conceptual framework of immersive experience.
- To discuss different dimensions of immersive “auditory” experience.

Multidimensionality

- Dictionary definitions (Oxford Learner's)
 - *“the act of putting somebody/something into a liquid, especially so that they or it are **completely covered**; the state of being covered by a liquid.”*
 - *“the state of being **completely involved** in something.”*

Perceptual/
Sensory

Passive
experience

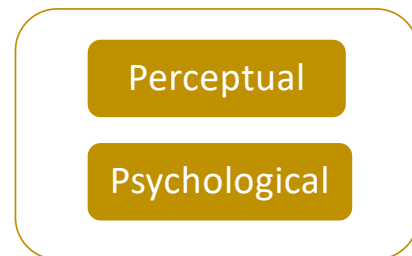
Cognitive

Active
experience

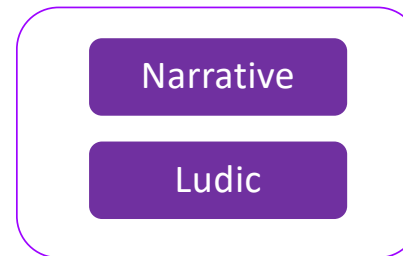
Multidimensionality

- Different immersion-related terms defined in the literature

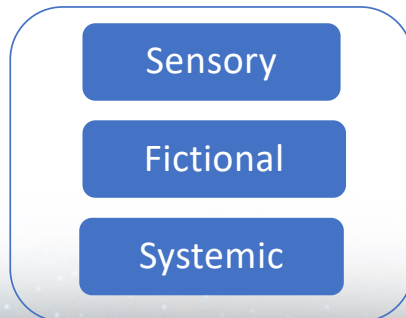
Lombard and Ditton (1997)



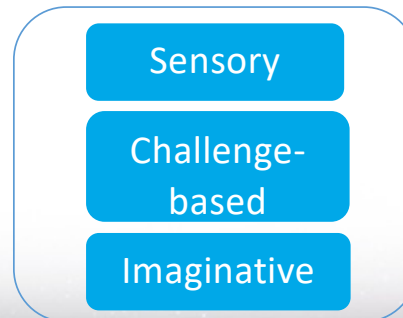
Ryan (2003)



Arsenault (2005)



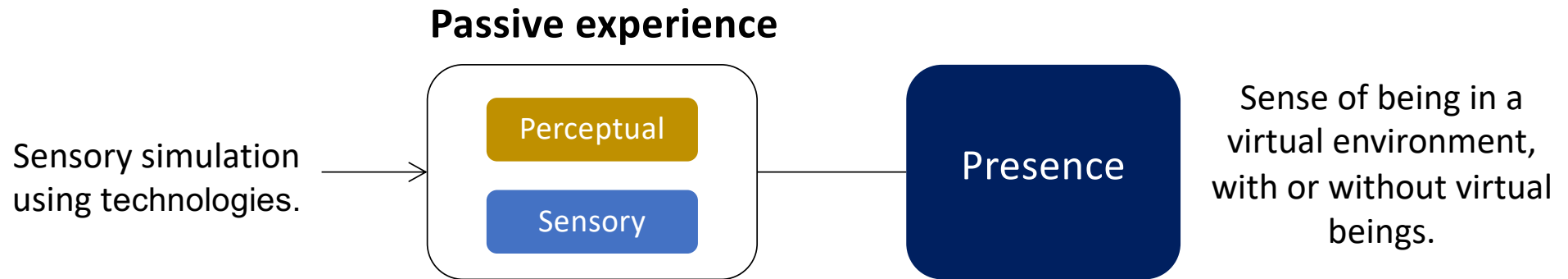
Ermi and Mäyrä (2005)



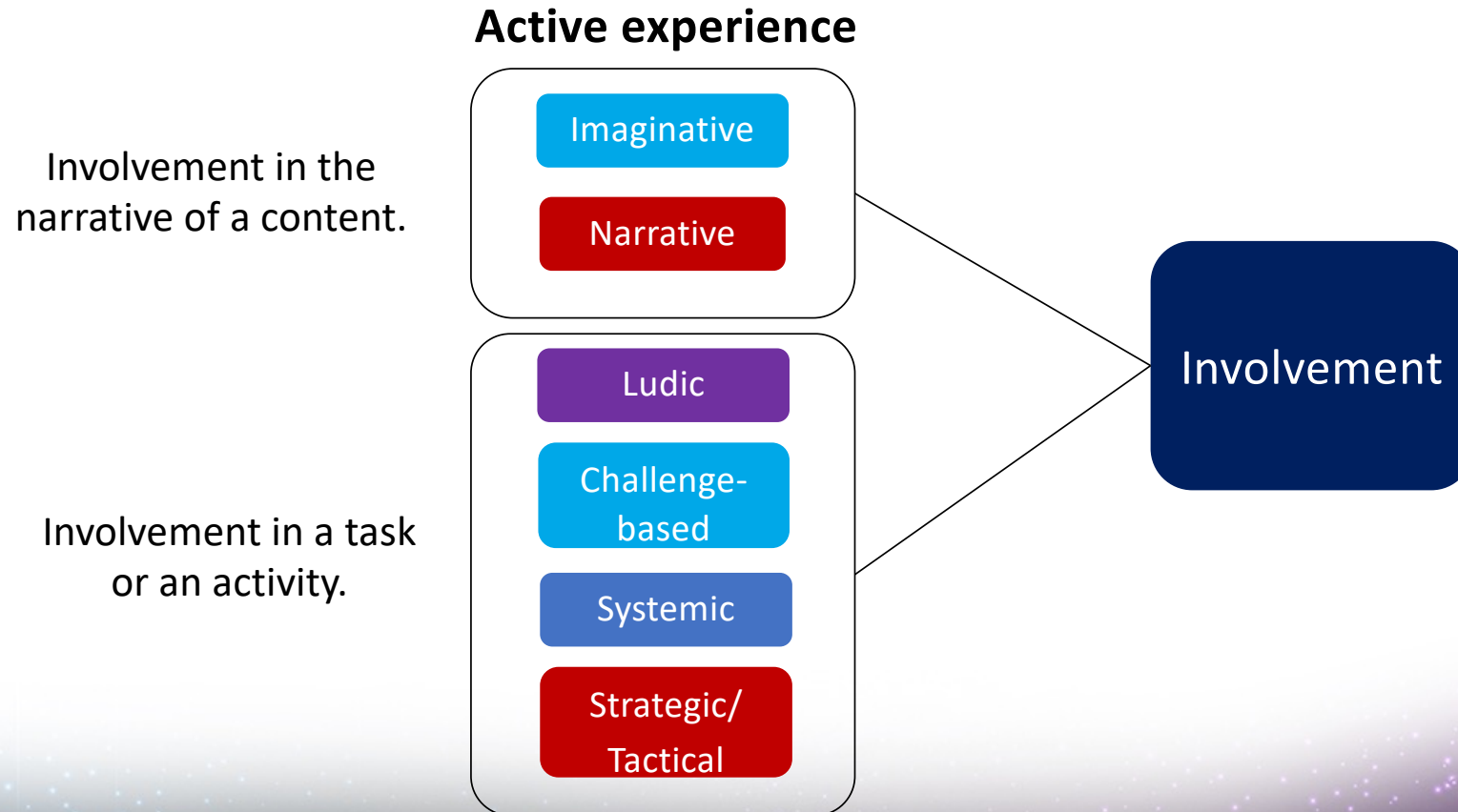
Adams and Rolling (2007)



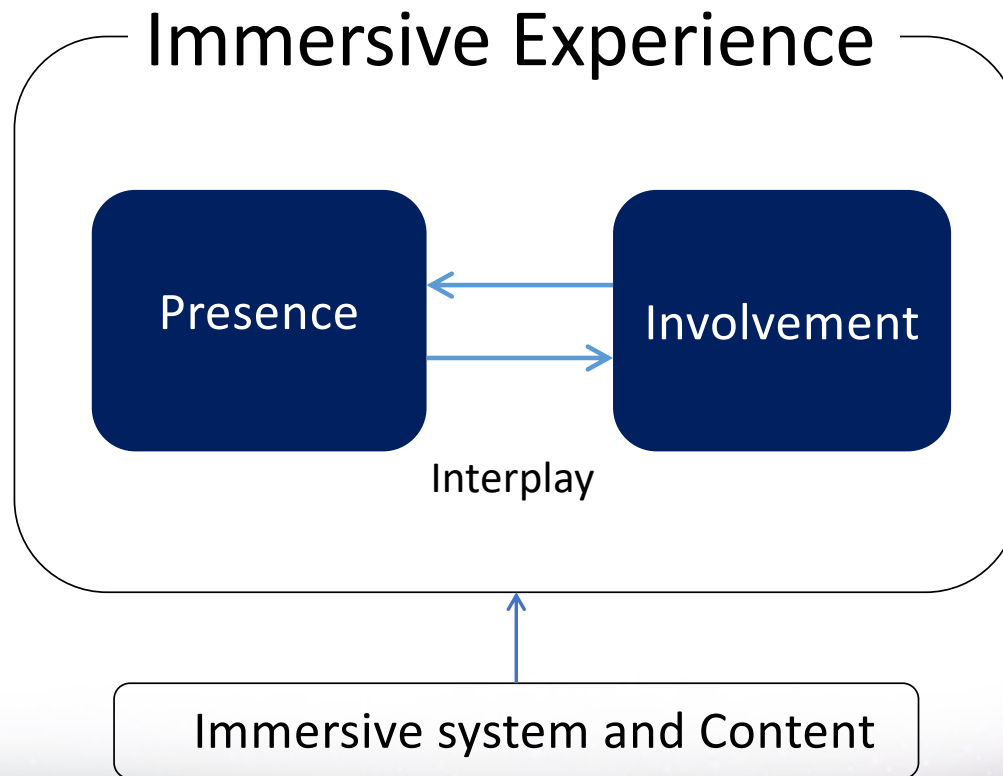
Multidimensionality



Multidimensionality



Multidimensionality



Potential confusion

- Standalone definitions of immersion

Witmer and Singer (1998)

“a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences”

Mainly a perceptual experience. The cognitive aspect not clearly implied.

Agrawal et al. (2020)

“a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world”

Mainly a cognitive experience. Narrative-induced transportation.

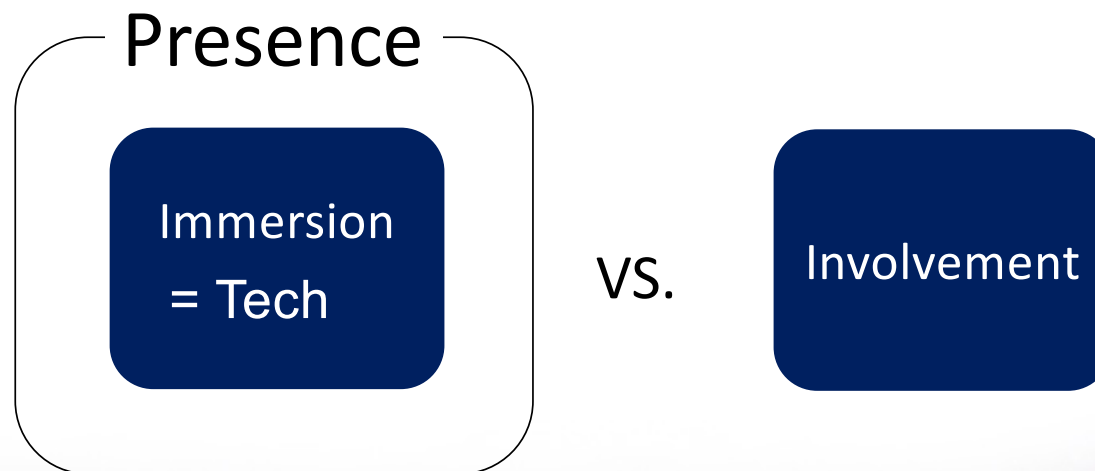
Potential confusion

- Slater (2003) and other “Presence” researchers
 - Immersion is a **technological process** rather than experience.
 - Immersion is a determinant of Presence.

e.g. The more immersive (the more advanced the technology is), the greater sense of presence.

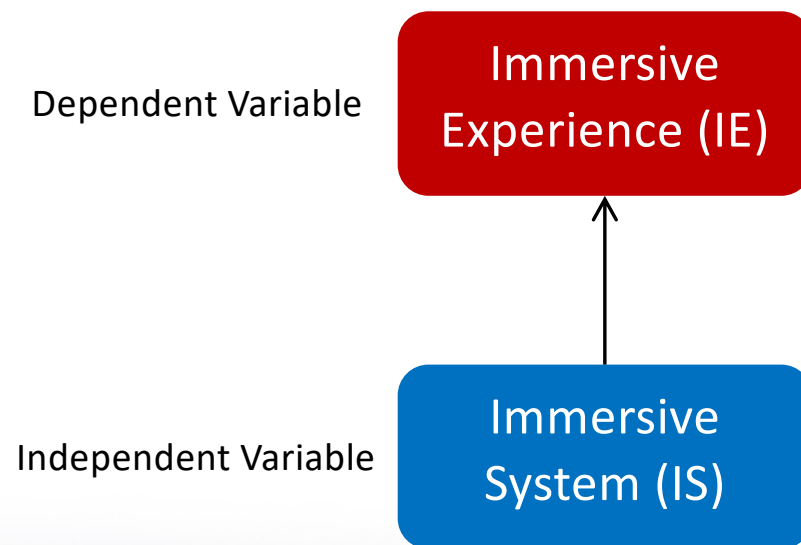
Potential confusion

- Slater (2003) and other “Presence” researchers



Proposed terminology

- To avoid confusion, it is proposed to say “**immersive experience**” and “**immersive system**” rather than just “immersion”.



Proposed terminology

- To avoid confusion, it is proposed to say “**immersive experience**” and “**immersive system**” rather than just “immersion”.

e.g. A higher level of immersion leads to a stronger sense of presence.

→ What does immersion mean here?

→ A more advanced *immersive system* can produce a stronger sense of presence.

→ A higher level of *immersive experience* leads to a stronger sense of presence (?).

→ A stronger sense of presence leads to a higher level of immersive experience.

Proposed IE model

- Lee (2020) “Conceptual model of immersive experience in extended reality” <https://psyarxiv.com/sefkh/>

The screenshot shows the PsyArXiv preprint page for the paper "A Conceptual Model of Immersive Experience in Extended Reality" by Hyunkook Lee. The page includes a navigation bar with options like "Submit a Preprint", "Search", "Donate", "Sign Up", and "Sign In". The main content area displays the title, author name, and author assertions (Conflict of Interest: No, Public Data: Not applicable, Preregistration: Not applicable). Below this, there is a "Download preprint" button and a "Downloads: 469" counter. A "plaudit" badge is also visible. The abstract text is displayed in a scrollable window, and a "See more" link is provided. The preprint DOI is also shown.

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A Conceptual Model of Immersive Experience in Extended Reality

AUTHORS
Hyunkook Lee

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Abstract

The term immersion or immersive is popularly used when describing and evaluating technologies in the area of extended reality (i.e., virtual/augmented/mixed reality). Much research has been conducted on immersion over the last few decades. However, there is still a lack of consistency in how the term is defined in the literature. Presence and involvement are other prominent concepts studied in the field of extended reality. However, there is currently no consensus on their relationship with immersion among researchers. This paper first discusses different dimensions of immersion as well as those of presence and

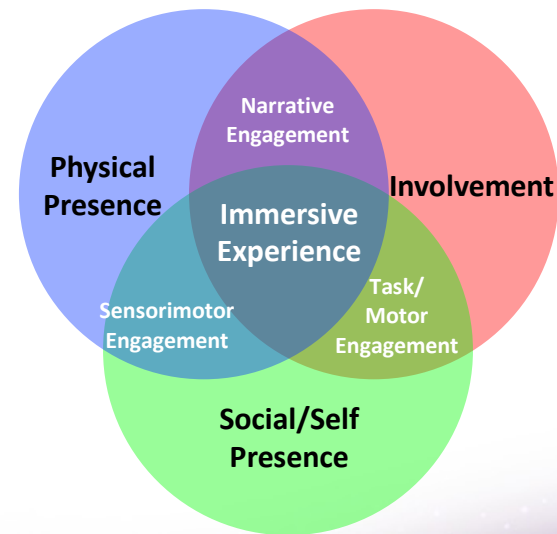
See more

Preprint DOI

Proposed IE model

- Lee (2020) “Conceptual model of immersive experience in extended reality” <https://psyarxiv.com/sefkh/>
- Immersive experience (IE) is multidimensional.
- Three high-level attributes of IE:

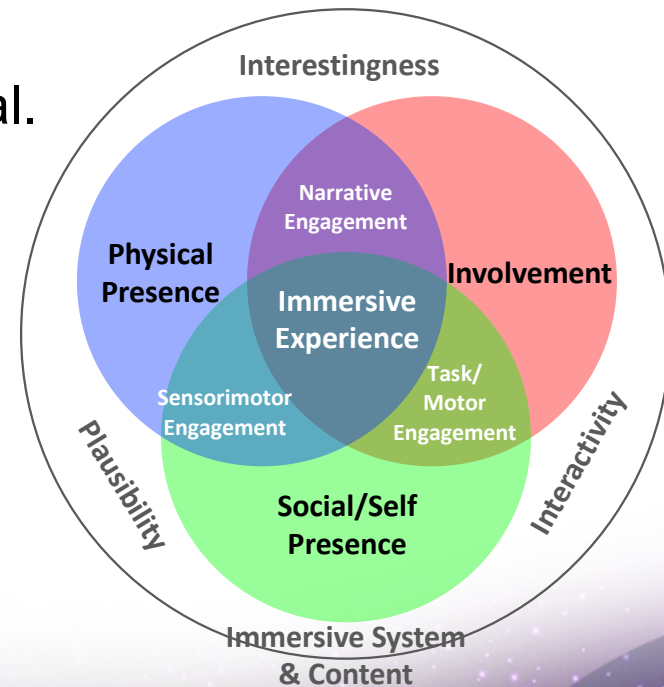
Physical Presence (PP)
Social/Self Presence (SP)
Involvement (INV)



Proposed IE model

- Lee (2020) “Conceptual model of immersive experience in extended reality” <https://psyarxiv.com/sefkh/>
- Immersive experience (IE) is multidimensional.
- Properties of Immersive system and content

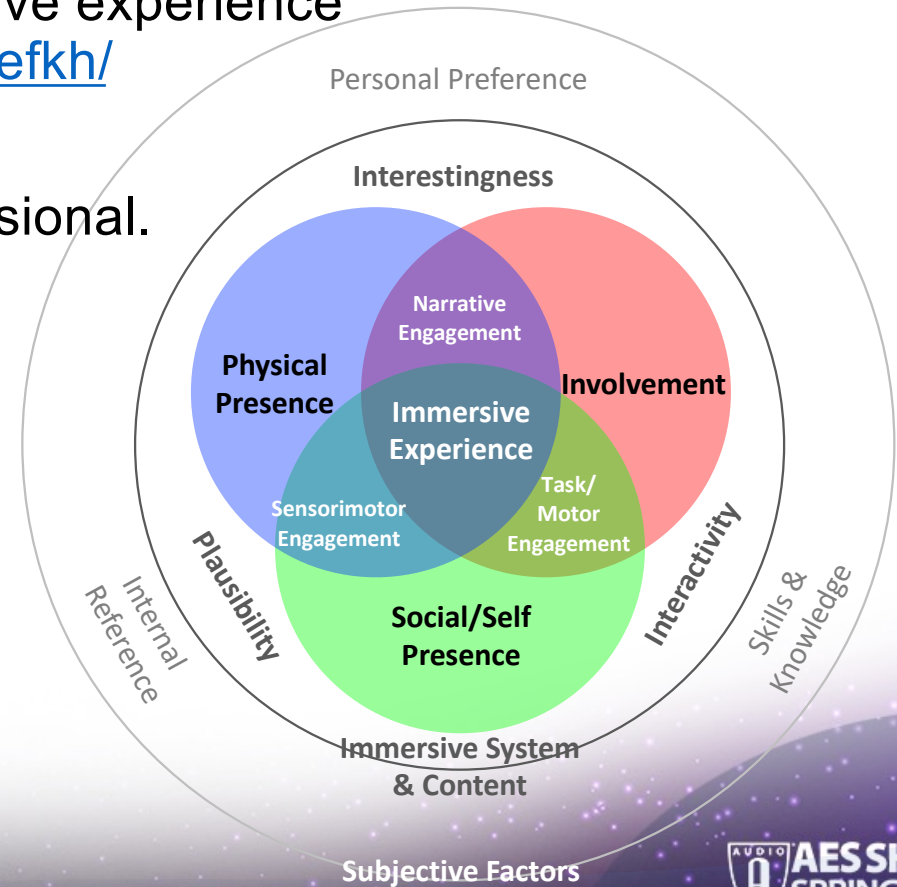
Plausibility
Interestingness
Interactivity



Proposed IE model

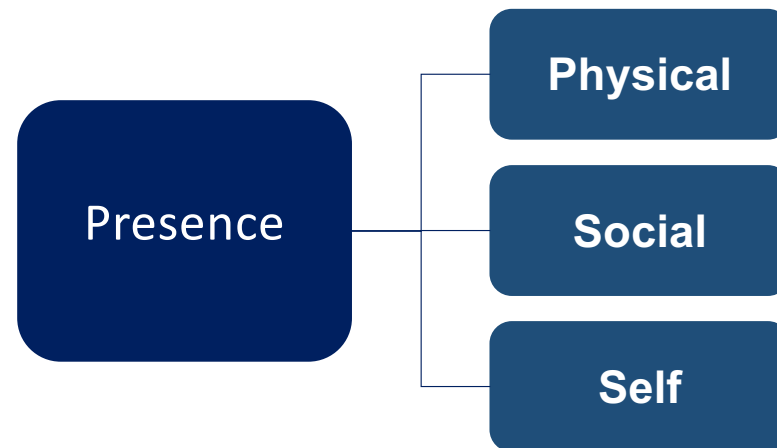
- Lee (2020) “Conceptual model of immersive experience in extended reality” <https://psyarxiv.com/sefkh/>
- Immersive experience (IE) is multidimensional.
- Subjective factors

Internal reference
Personal preference
Skills & knowledge



Presence

- Presence is also multidimensional (Biocca 1997).



Physical Presence

- The sense of being in a virtual environment.
- PP is usually considered as a consequence of **sensory** simulation, but it can also involve a **cognitive** process.
 - Brown and Cairns (2004): PP is achieved through *engagement* and *engrossment* in a task or activity.
 - Witmer and Singer (1998): the level of presence is determined by *selective attention* as well as sensory fidelity.

Physical Presence

- PP can occur without any sensorimotor simulation, e.g. through the narrative of a novel.
 - Narrative engagement, narrative absorption, narrative transportation.
- For technology-mediated IE, there is always a certain level of sensory simulation, so purely narrative-based PP is unlikely.
- The more advanced the immersive system is, **the more likely it will reduce the cognitive load required for PP.**

Social Presence

- “the degree to which the user feels access to the intelligence, intentions, and sensory impressions of another” (Biocca 1997).

→ Both perceptual and cognitive.

- Minimum level: simply sensing the presence of another intelligence.
- Higher level: **interaction** with the virtual beings at an **intelligent/emotional level**.



Self Presence

- A virtual self is experienced as the actual self.
 - Represents the technology user's mental model of him/herself inside the VE, and the physiological and emotional states
 - Three levels of self-presence (Ratan 2012)
 1. **Proto-self:** how realistic the virtual self representation is.
 2. **Core-self:** induced through social interactions with mediated objects (necessitating Social Presence).
 3. **Extended self:** through intelligent or/and emotional communion with virtual beings.



Involvement

- Calleja (2007)'s six dimensions of Involvement in Games.
 - Tactical, performative, affective, shared, narrative and spatial
- Brown and Cairns (2004): Three steps of involvement in game play.
 1. **Engagement** = the first step of involvement with a game.
 2. **Engrossment** = the next level of involvement (emotional attachment).
 3. **Total immersion** = Presence.

Flow

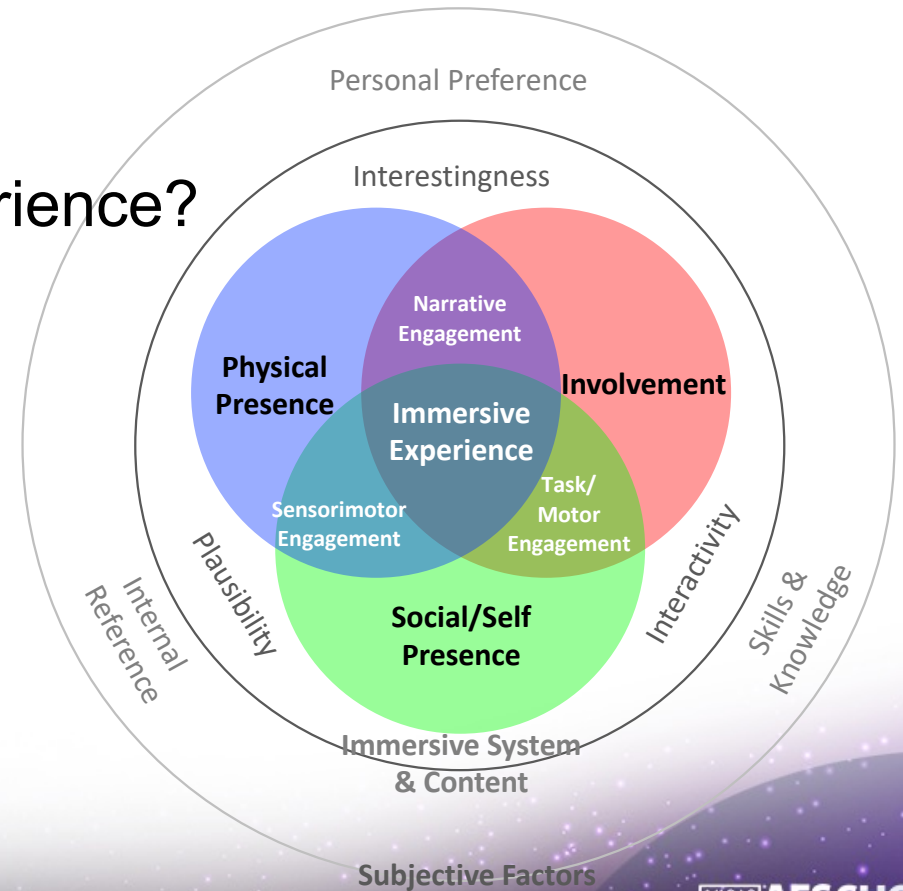
- A famous concept by Csikszentmihalyi (1990).
- *“An optimal experience for happiness”*
 - Mainly about **enjoyment**.
- Separated from the proposed IE model.
 - An experience might be very immersive but not enjoyable.
 - e.g. boxing game in VR



Proposed IE model

What about Immersive *Auditory* Experience?

- Physical Presence
- Social/self Presence (VR/AR)
- Involvement



Involvement & Presence

Use Headphones



stereo



Binaural with virtual acoustics



Track: Universe by meHiLove

Involvement & Presence

Grand central terminal, Manhattan



Binauralised ESMA-3D



Central Park, Manhattan

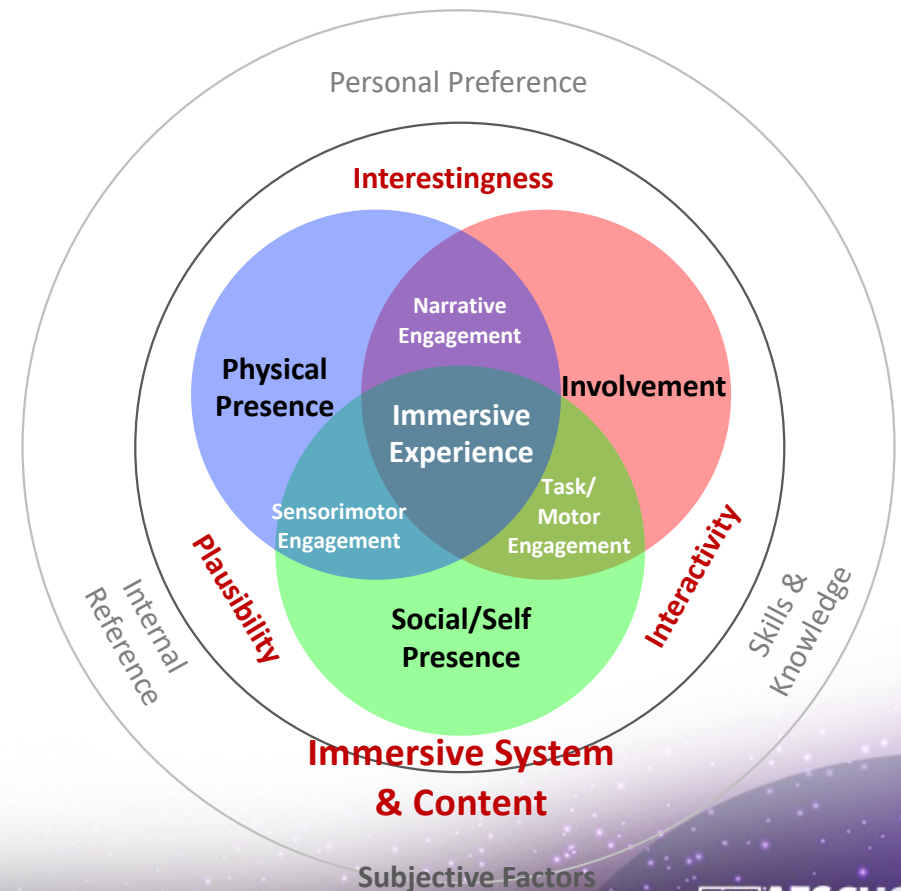


Binauralised ESMA-3D



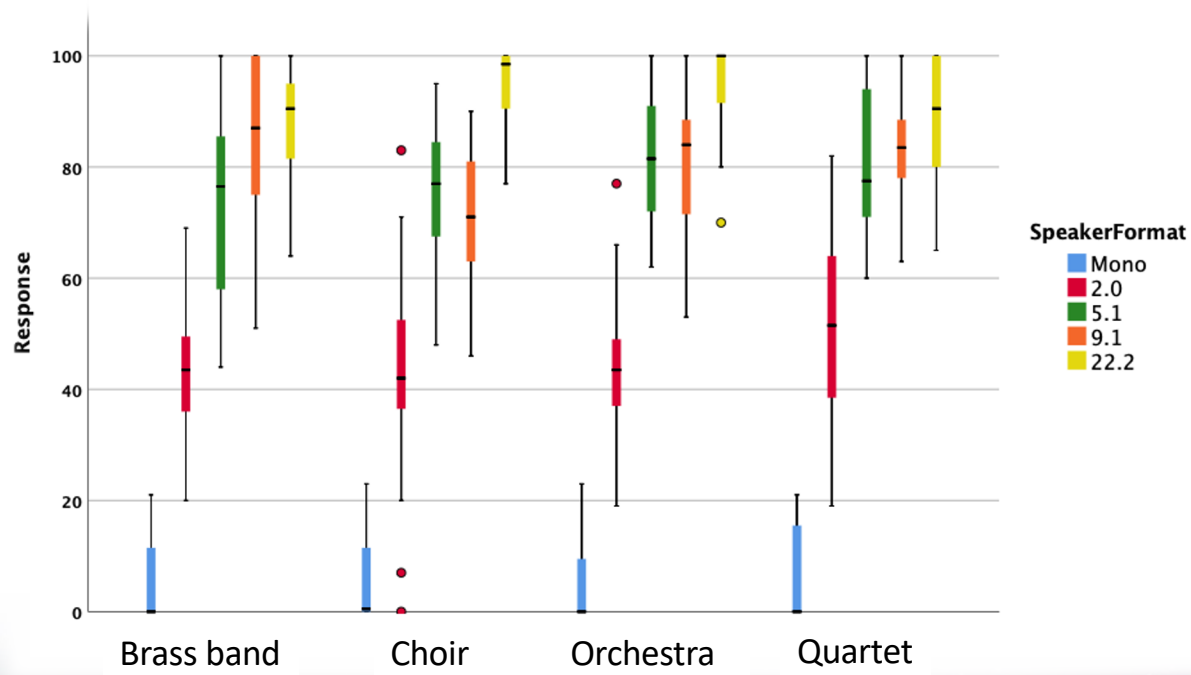
IS and Content

- Immersive system
 - 3D loudspeaker array, 3D mic array, Panning, Reverb, Binauraliser, Head/motion tracking, etc.
- Content
 - Content type, subjective preference
- Both are important for **Plausibility**, **Interestingness** and **Interactivity**.



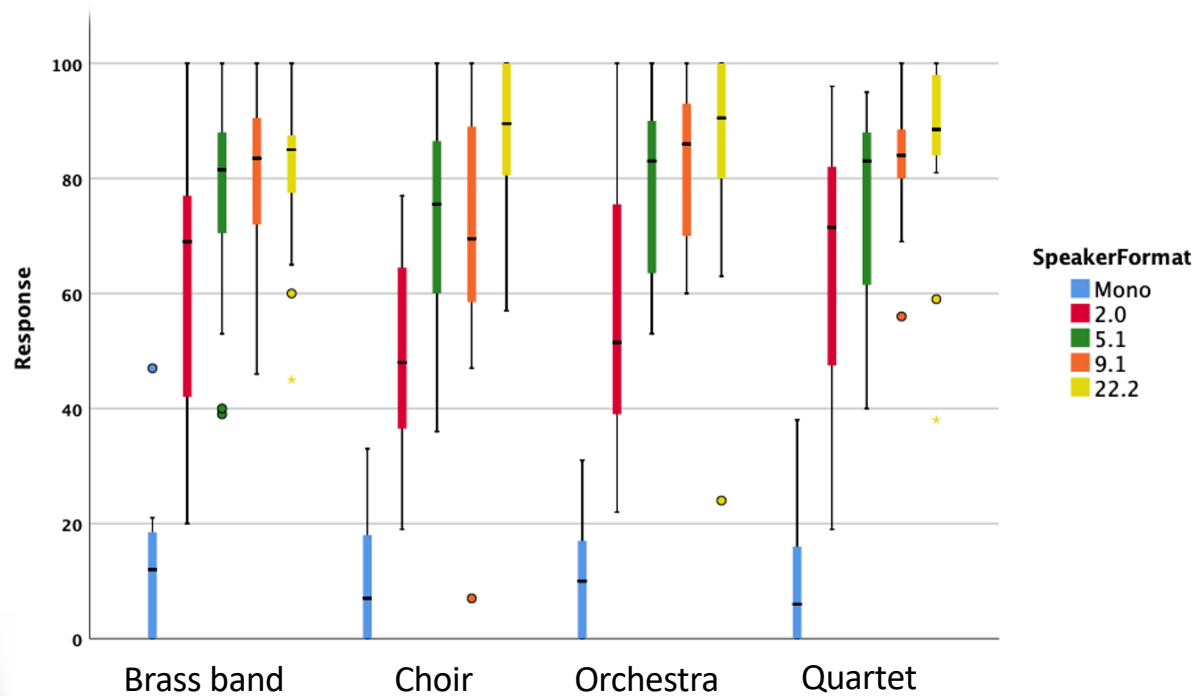
Immersive system

- Speaker format comparisons (downmixed from 22.2) in [Listener Envelopment](#)



Immersive system

- Speaker format comparisons (downmixed from 22.2) in Presence



Immersive system

- Speaker configurations? Downmix algorithms?
- More speakers do not automatically mean more present or more immersive.
- Content dependency.
- Subjective factors (culture, experience, age, etc.)
- Production techniques
 - What is the best way to create immersive content that can fully benefit from a given immersive system?

Immersive system

- 3D loudspeaker configurations and playback systems

ITU-R BS.2051-2

ITU-R BS.2159-4



Immersive system

- 3D microphone array review paper

Open access review paper in JAES

<https://www.aes.org/e-lib/browse.cfm?elib=21013>

PAPERS

OPEN ACCESS Freely available online



H. Lee, "Multichannel 3D
Microphone Arrays: A Review"
J. Audio Eng. Soc., vol. 69, no. 1/2, pp. 5–26, (2021 January/February).
DOI: <https://doi.org/10.17743/jaes.2020.0069>

Multichannel 3D Microphone Arrays: A Review

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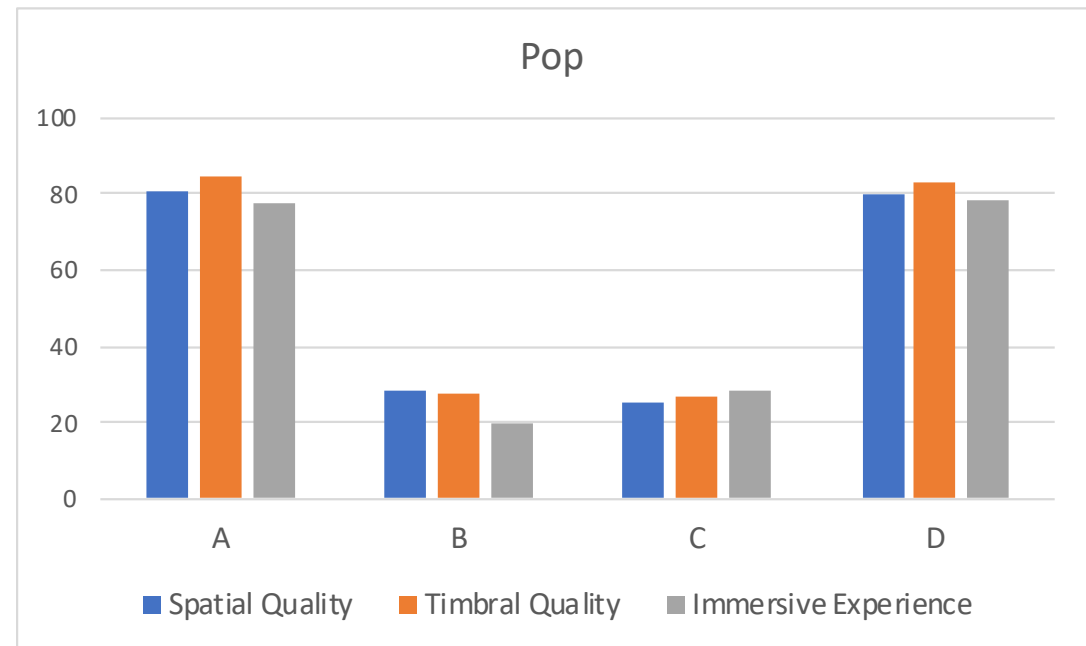
Applied Psychoacoustics Lab (APL), University of Huddersfield, Huddersfield, United Kingdom

Along with the recent advance of multichannel 3D audio technologies, a number of new microphone techniques for 3D sound recording have been proposed over the years. To choose a technique that is most suitable for the intended goal of a recording, it is first necessary to understand the design principles, pros, and cons of different techniques. This paper first categorizes existing 3D microphone arrays according to their physical configurations, design philosophies, and purposes, followed by an overview of each array. Studies that have subjectively or objectively evaluated different microphone arrays are also reviewed. Different approaches in the configuration of upper microphone layer are discussed, aiming to provide theoretical and practical insights into how they can contribute to creating an immersive auditory experience. Finally, limitations of previous studies and future research topics in 3D sound recording are identified.

Content production

Timbral quality is as important as spatial quality for IE.

	Drums	Guitar	Vocal
A	stereo	stereo	stereo
B	Binaural	Binaural	Binaural
C	Binaural	stereo	Binaural
D	stereo	Binaural	stereo

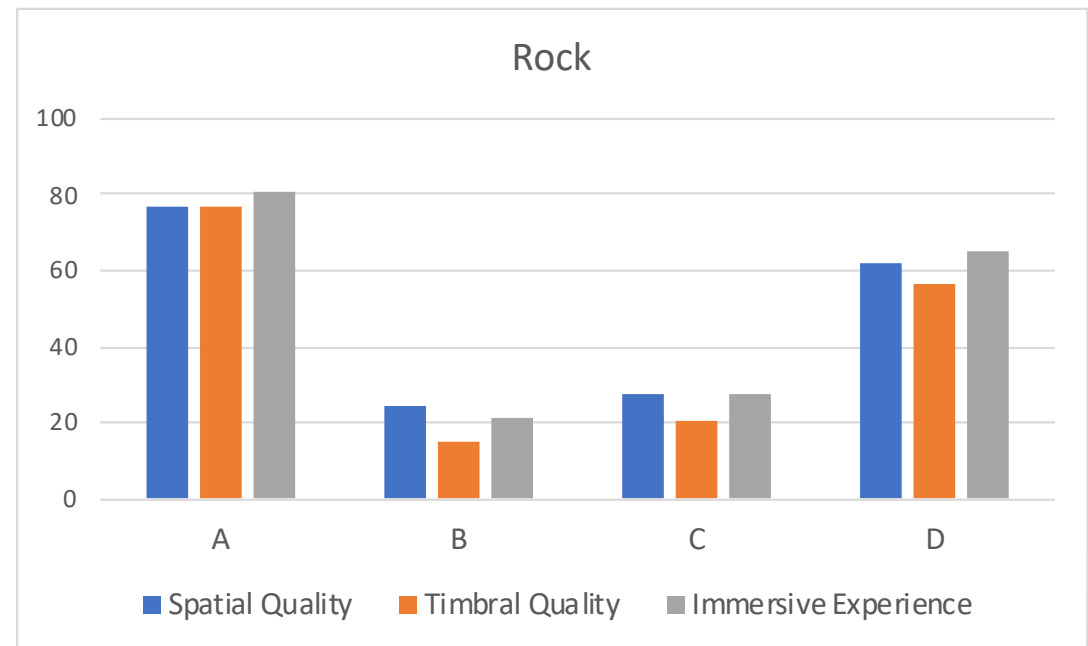


P. A. Morell And H. Lee, 2021, "Factors of immersive experience in binaural music production", Forthcoming.

Content production

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C	Binaural	stereo	Binaural
D	stereo	Binaural	stereo



P. A. Morell And H. Lee, 2021, "Factors of immersive experience in binaural music production", Forthcoming.

Content production

- Binauralisation often causes colouration (affecting involvement?)
- Subjective factors.
- Spatial “contrast” (internal vs. external) seems to be useful.
- Need to explore binaural mixing techniques.
→ Involvement + Presence

Plausibility

- A property of Immersive System, related to **Presence**.
- Slater (2009): **“Plausibility Illusion”**
 - *“determined by the extent to which the system can produce events that directly relate to the participant, the **overall credibility of the scenario being depicted in comparison with expectations.**”*
 - It occurs even though the user knows that the virtual objects are not there in real life.

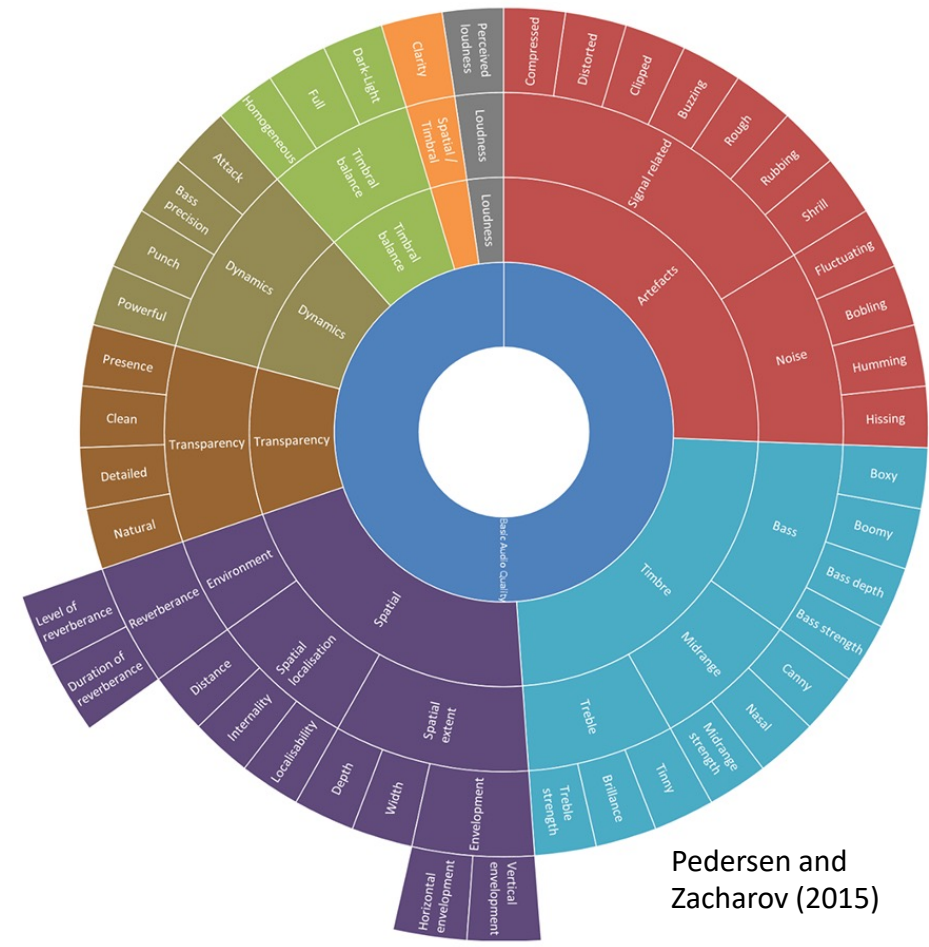
Plausibility

- Technical factors
 - Without a good sensory simulation, heavier cognitive load might be required for the user to have a plausibility illusion.
- Sensorimotor contingency (SMC)
 - Our sensory perception is linked with our motion (O'regan and Noe 2001).
 - e.g. Auditory localisation: By moving our head or/and body, we can localise sound more accurately (Front/Back, Up/Down).



Plausibility

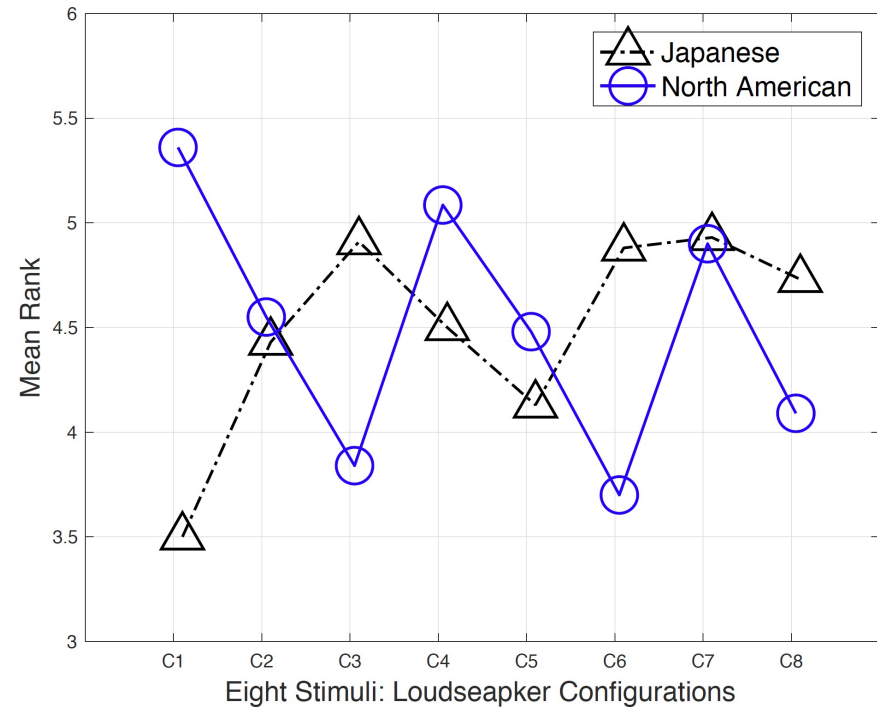
- Subjective quality factors
 - How natural and acceptable are the attributes rendered by the system?
 - Not only spatial attributes but also timbral attributes would be important for plausibility.



Plausibility

- Contextual factors

- Culture
- Gender
- Age
- Expertise
- Environment
- Etc.



Kim, S., Ko, D., Nagendra, A., and Woszczyk, W., Subjective evaluation of multichannel sound with surround-height channels. In: Proc. of AES 135th Int. Conv., New York, USA (2013).

Plausibility

- Does Plausibility require the exact replication of real life events?
- Social realism vs. Perceptual realism (Lombard and Ditton 1997)
 - **Social realism**: how likely virtual stimuli would occur in real life.
 - **Perceptual realism**: how close the implementation of the stimuli is to one's expectation *if they existed in real life*.

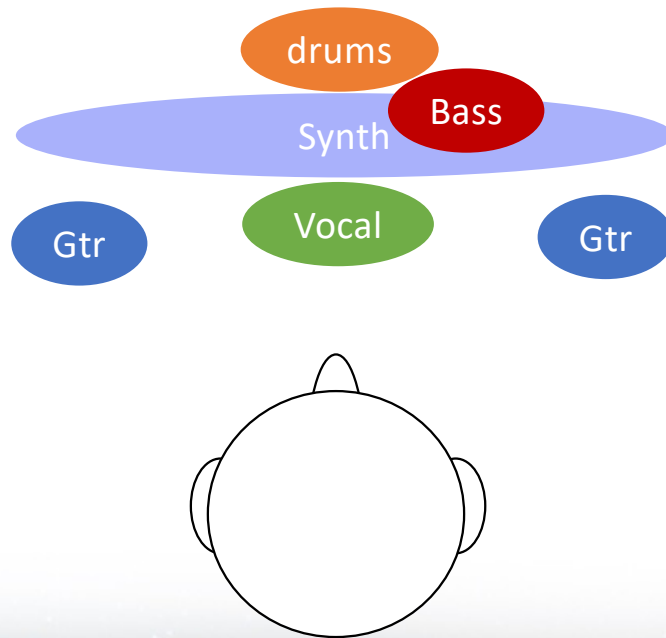


Plausibility

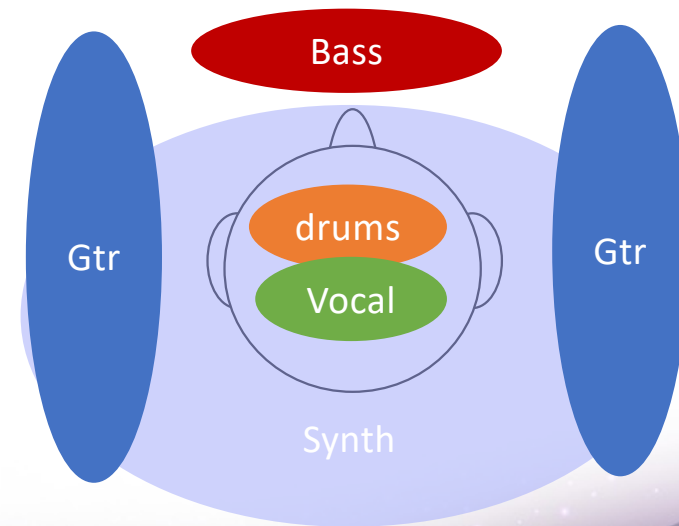
- Plausibility is about the system user's **internal reference**.
- For IE, the immersive system does not have to replicate the physical environment exactly, but needs to produce the necessary perceptual cues to **plausibly represent** the environment.

Plausibility

- Social realism vs. Perceptual realism in binaural mixing?

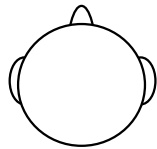


VS.

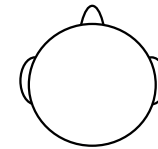
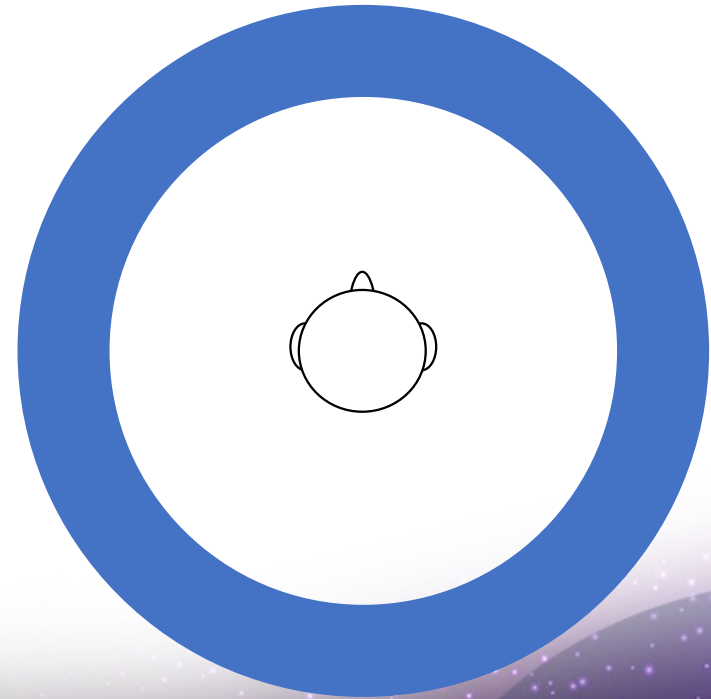


Plausibility

- Acoustic 3D recording

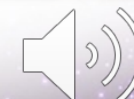
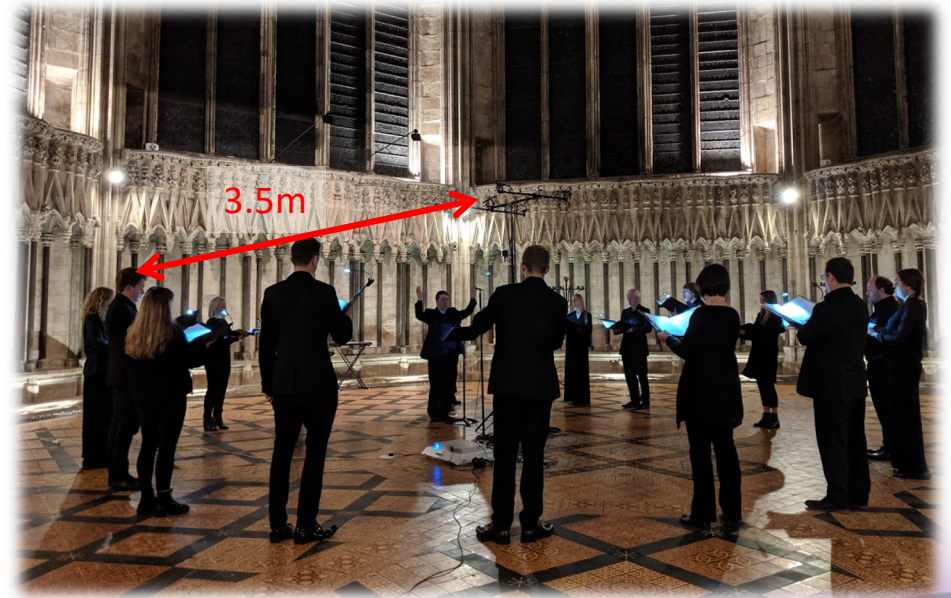
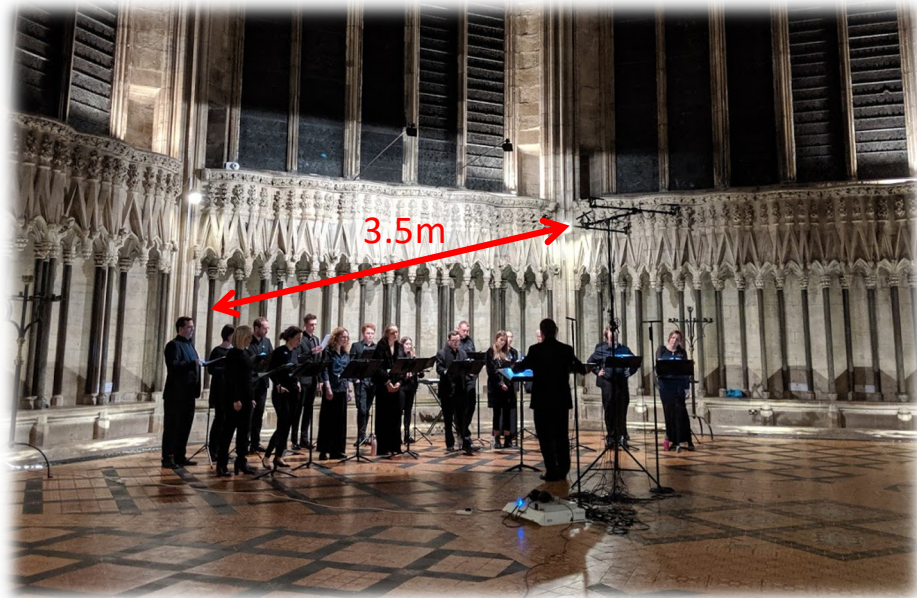


VS.



Plausibility

- Acoustic 3D recording – Ebor Singers at York Minster



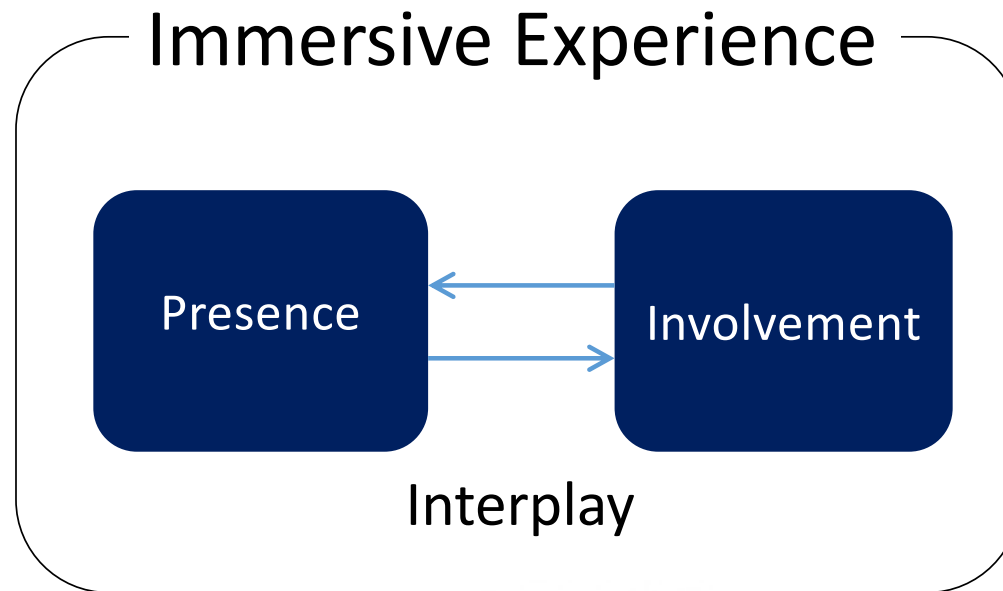
Plausibility

- Binaural Ambient Music – transportation into an *imaginary* space

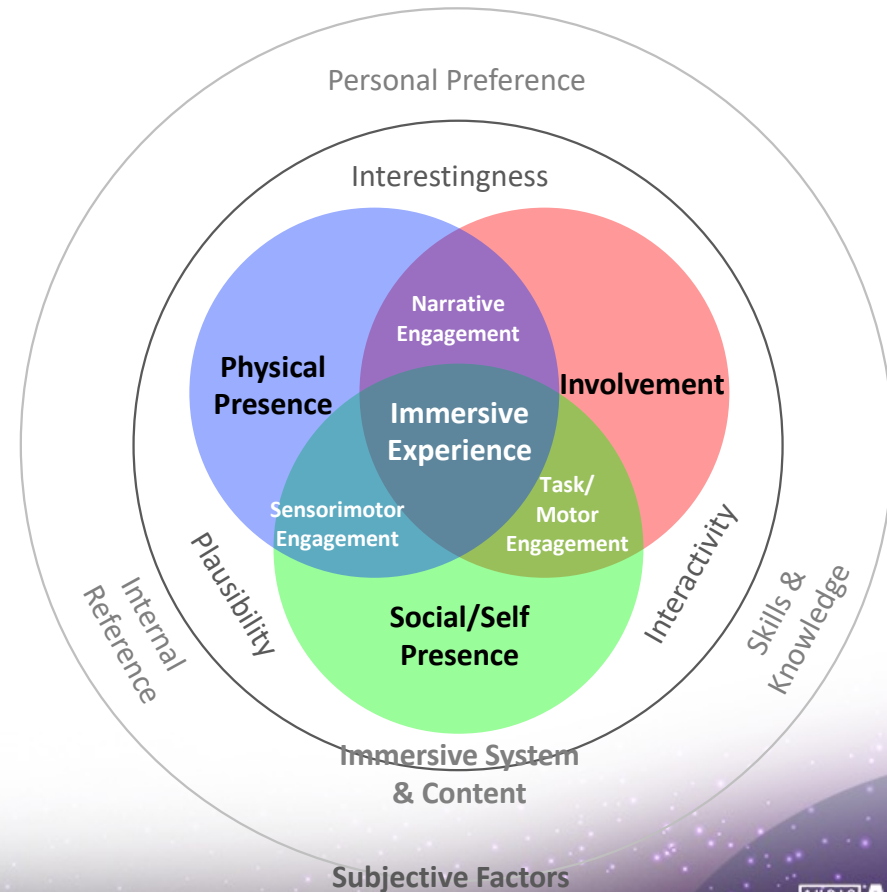
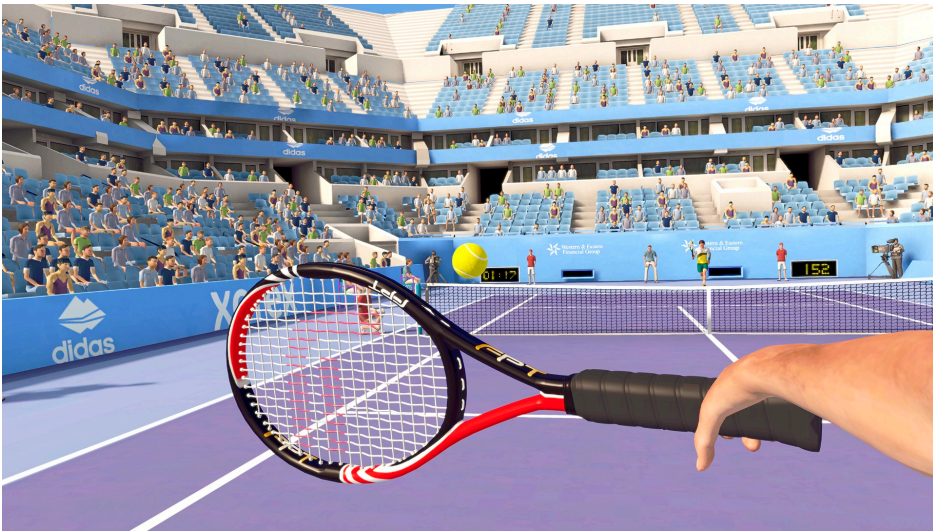
Stereo tracks
processed in binaural



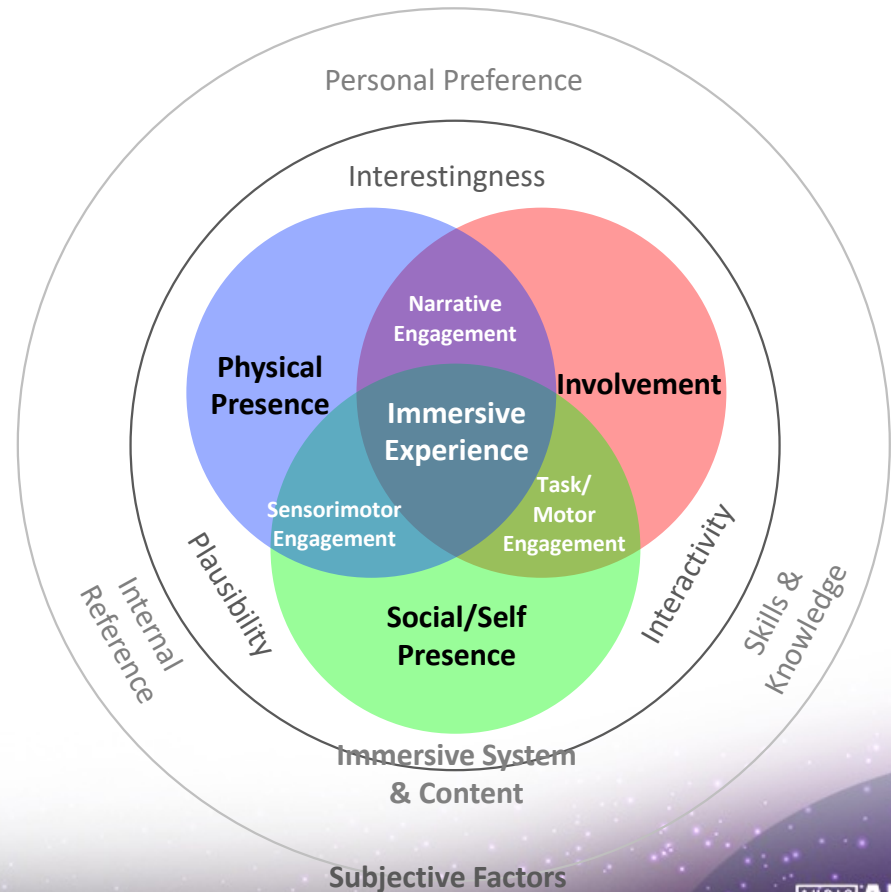
Presence & Involvement



Immersive Audio for VR



Immersive Audio for AR



Conclusions

- Immersive audio system does not automatically provide an immersive auditory experience.
- Presence and Involvement interplay for an immersive auditory experience.
- Plausibility is not just about making it similar to real life event (social realism), but also about creativity (perceptual realism).
- We should not just rely on immersive systems, but also actively explore new production techniques to make content more involving.

Thank you for listening.

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