LUND UNIVERSITY

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Hacking the brain:

How Spatial Audio Makes Latency Vanish

Imagine watching The Phantom of the Opera. The orchestra reaches the dramatic moment when the Phantom should appear under the chandelier but the stage effect fails, and he arrives late. The music and visuals no longer match, ruining the experience. The same problem occurs in online opera experiences, we call it latency.

The Survival Crisis Facing Opera Houses

Many modern opera houses face a shared challenge: their audiences are aging. The average opera-goer is often over 60 and typically comes from a higher socioeconomic background. Meanwhile, younger generations frequently perceive opera as less accessible, less relevant, or less engaging compared to other entertainment forms.

This demographic shift has motivated opera companies to explore digital transformation strategies, including streaming services, interactive content, and new forms of audience engagement. Among these, virtual reality (VR) combined with spatial audio has emerged as a promising approach. By creating immersive digital performances, VR can place audiences at the center of the stage, allowing them to experience opera from within the performance space.

Audiovisual Delay Perception

Do people notice when audio and video are out of sync? How sensitive are they to such temporal mismatches? To answer these questions, we collected data from three sources:

- **Behavioral responses:** Participants were asked to judge the temporal relationship between audio and video, indicating whether the sound arrived before the image or vice versa.
- **Eye-tracking recordings:** We captured participants' gaze behavior while they watched the stimuli.
- **Subjective questionnaires:** Participants also reported their experiences using a set of self-assessment measures, including perceived presence, naturalness, confidence, task difficulty, and mental effort.

The Brain Misses Small Timing Errors

Instead of solely removing latency, VR systems may reduce its perceptual impact. Spatial audio adds directional and environmental cues, increasing cognitive load and reducing sensitivity to timing errors.

Participants tolerated delays up to 461 ms with spatial audio, more than double that of stereo audio. This suggests that richer audio environments shift attention from timing precision to spatial processing.

The Future of Streaming Opera

Rather than focusing only on eliminating latency, spatial audio may help maintain immersion even when small delays remain.

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