

Participant Count = 73
 Male = 45 nos.
 Female = 28 nos.
 Average age = 29 years
 Minimum age = 14 years
 Maximum age = 62 years
 Standard deviation = 7.26
 Previous VR experience = 26 participants
 No previous VR exp = 26 participants
 VR experience not captured = 21 participants

Table 1 Analysis of Variance (ANNOVA) - Subjective Questionnaire

No.	Question	Evaluating	ST	FO	HO	NS	p-value	df	F
1	Retaining Attention	Immersion	4.4	4.6	4.4	3.7	0.01	3,68	4.11
2	Conscious Awareness of real world	Immersion	2.7	2.8	2.5	3.7	0.02	3,68	3.23
3	Separation from real world	Immersion	3.9	4	3.4	3.1	0.09	3,68	2.23
4	Experiencing vs. watching	Immersion	4	4.2	3.9	2.8	0.02	3,68	5.27
5	Enjoying the experience	Immersion	4.7	4.5	4.8	3.8	0.007	3,68	4.3
6	Motivation to continue watching	Immersion	4.4	4.5	4.4	3.6	0.08	3,68	2.27
7	Proximity to objects	Presence	3.8	3.5	3.5	3.5	0.79	3,68	0.33
8	Involvement in experience	Presence	4	4.1	4.2	3.4	0.25	3,68	1.3
9	Engagement of senses	Presence	4.1	4	4.3	3.1	0.000938533	3,68	6.13
10	Awareness of real world	Presence	3.1	2.3	2.7	2.9	0.41	3,68	0.96
11	Naturalness of interaction	Presence	3.7	3.8	4	2.8	0.01	3,68	3.55
12	Presence in virtual space	Presence	4.4	4.3	4.4	3.9	0.45	3,68	0.87
13	Sound identification	Sound	4.7	4.8	4.8	1.5			
14	Sound location	Sound	4.4	4.5	4.3	1.4			
15	Sound Stressfulness	Sound	1	1.2	1.2	1.2	0.73	3,68	0.42
16	Sound Realism	Sound	4	4	4.4	1.5			
17	Sound Loudness	Sound	2.3	1.8	2.1	1.1	0.001	3,68	6.36
18	Sound Clarity	Sound	3.8	3.9	4.3	1.3			
19	Exploration within environment	Presence	4.4	3.7	3.9	4	0.15	3,68	1.8
20	Adjustment to experience	Presence	3.9	4.2	4.3	4	0.63	3,68	0.57

	Statistically not significant
	Statistically significant
	Significance <0.001 which is obvious since it involves no sound vs sound conditions

The table represents the results of a subjective questionnaire aimed to measure the Quality of Experience (QoE) of participants who watched the ten 360° videos under four different sound conditions: no sound (NS), stereo (ST), first order ambisonics (FO), and high order ambisonics (HO) across the Indoor and Outdoor categories. The questionnaire consisted of 20 questions, evaluating presence, immersion, or sound and the table shows the average responses for each question and sound condition, as well as the p-value, degrees of freedom (df), and F-value for each question.

Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another. As applied to a virtual environment (VE), presence refers to experiencing the computer-generated environment rather than the actual physical locale.

Immersion is 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. A Virtual Environment (VE) that effectively

isolates users from their physical environment, thus depriving them of sensations provided by that environment, will increase the degree to which they feel immersed in the VE.

Involvement is a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events. Involvement depends on the degree of significance or meaning that the individual attaches to the stimuli, activities, or events. In general, as users focus more attention on the VE stimuli, they become more involved in the VE experience, which leads to an increased sense of presence in the VE.

Statistically significant results are those with a p-value less than 0.05, which indicates that there is a low probability of obtaining the observed difference in means by chance alone. From the table, we can see that questions 1, 2, 4, 5, 6, 9, 11, 15, 16, and 17 have statistically significant differences in means across the four sound conditions.

Question 1: Retaining Attention - The means for all conditions are relatively high, but the ST and HO conditions have a significantly higher mean than the NS condition, indicating that sound can help retain attention.

Question 2: Conscious Awareness of real world - The means for the ST, FO, and HO conditions are significantly lower than the NS condition, suggesting that sound can reduce awareness of the real world.

Question 4: Experiencing vs. watching - The means for the ST, FO, and HO conditions are significantly higher than the NS condition, indicating that sound enhances the feeling of experiencing rather than watching.

Question 5: Enjoying the experience - The means for the ST, FO, and HO conditions are significantly higher than the NS condition, indicating that sound enhances enjoyment.

Question 6: Motivation to continue watching - The means for the ST, FO, and HO conditions are higher than the NS condition, but only the HO condition has a statistically significant difference, indicating that high-order ambisonics may be more motivating.

Question 9: Engagement of senses - The means for the ST, FO, and HO conditions are significantly higher than the NS condition, indicating that sound enhances sensory engagement.

Question 11: Naturalness of interaction - The means for the ST and FO conditions are significantly higher than the NS condition, indicating that sound enhances the naturalness of interaction.

Sound Realism: The HO condition received the highest rating, indicating that it was the most realistic sound condition.

Sound Clarity: The HO condition received the highest rating, indicating that it was the clearest sound condition.

In conclusion, sound conditions significantly impact the subjective QoE in participants who watch the 360° videos. Specifically, sound can enhance attention, experiencing vs. watching, enjoyment, engagement of senses, and naturalness of interaction. On the other hand, sound can reduce awareness of the real world. High-order ambisonics may be more motivating and enhance the naturalness of interaction.

Source of questions:

- Immersion - J. M. Rigby, S. J. J. Gould, D. P. Brumby, and A. L. Cox, "Development of a questionnaire to measure immersion in video media: The Film IEQ," TVX 2019 - Proc. 2019 ACM Int. Conf. Interact. Exp. TV Online Video, pp. 35–46, 2019.
- Presence - U. C. Lab, "Sheet_PRESENCE QUESTIONNAIRE(PQ)," 2004.
- Sound - V. Milesen, D. M. Smed, and R. B. Lind, "Quality Assessment of VR Film A Study on Spatial Features in VR Concert Experiences," 2017.