

# The Awe-some Spectrum: Self-Reported Awe Varies by Eliciting Scenery and Presence in Virtual Reality, and the User's Nationality

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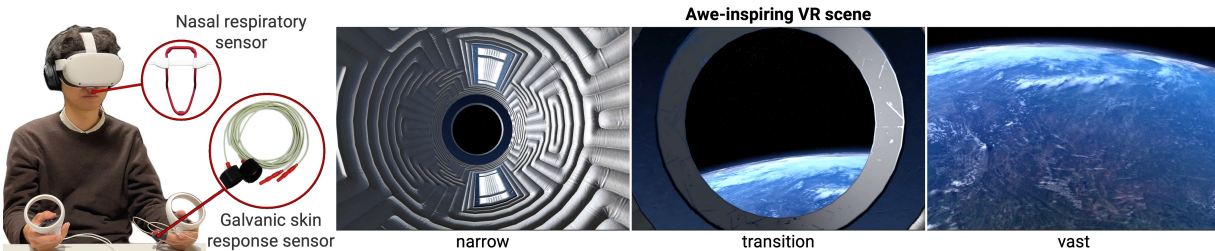


Figure 1: A setup for eliciting awe in VR. Left: the experiment setup, user wearing a VR head mounted display (HMD) and two biosensors: a respiration sensor and a galvanic skin conductance (GSR) sensor. The user will experience 10 different scenes. Right: The *Space* scene - designed to elicit awe. All awe-inspiring scenes have a narrow and a vast area.

## ABSTRACT

Awe is a multifaceted emotion often associated with the perception of vastness, that challenges existing mental frameworks. Despite its growing relevance in affective computing and psychological research, awe remains difficult to elicit and measure. This raises the research questions of how awe can be effectively elicited, which factors are associated with the experience of awe, and whether it can reliably be measured using biosensors. For this study, we designed 10 immersive Virtual Reality (VR) scenes with dynamic transitions from narrow to vast environments. These scenes were used to explore how awe relates to environmental features (abstract, human-made, nature), personality traits, and country of origin. We

collected skin conductance, respiration, self-reported awe and presence data from participants from Germany, Japan, and Jordan. Our results indicate that self-reported awe varies significantly across countries and scene types. In particular, a scene depicting outer space elicited the strongest awe. Scenes that elicited high self-reported awe also induced a stronger sense of presence. However, we found no evidence that awe ratings are correlated with physiological responses. These findings challenge the assumption that awe is reliably reflected in autonomic arousal and underscore the importance of cultural and perceptual context. Our study offers new insights into how immersive VR can be designed to elicit awe, and suggests that subjective reports – rather than physiological signals – remain the most consistent indicators of emotional impact.

**Index Terms:** Awe, Virtual Reality, Skin Conductance, Respiration

## 1 INTRODUCTION

Awe is a self-transcendent emotion characterized by the perception of vastness and the need to accommodate this vastness into one's existing mental frameworks [28]. It is often triggered by stimuli that challenge our understanding of the world, such as natural landscapes [24], architectural structures [28], or powerful music [36]. Experiencing awe has been linked to various positive psychological effects, including increased prosocial behavior, humility, and life satisfaction [28].

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Recently, researchers have begun to explore awe's potential as a tool for mental health interventions. It has been described as a transformative emotion with the ability to shift attention away from the self and open individuals to new perspectives [11]. These qualities may be especially relevant for treating conditions such as depression [11] and acute physical pain [50]. However, the use of awe in clinical or therapeutic contexts is still in its early stages, and more empirical research is needed to understand how it can be reliably elicited and applied. In addition to its psychological impact, awe has also been linked to distinct physiological responses. These include changes in pupil dilation, breathing patterns, and electrodermal activity, such as skin conductance responses (SCR) and skin conductance level (SCL) [54, 62, 57]. These reactions suggest that awe is not only a subjective experience but also a measurable physiological phenomenon.

Virtual Reality (VR) has emerged as a promising tool to study awe in controlled experimental settings. VR enables the creation of immersive, interactive, and highly realistic environments, which are well suited to replicate the perceptual characteristics of awe-inducing scenes. Compared to traditional media like videos or images, VR offers greater fidelity and a stronger sense of presence, which can enhance emotional engagement [13]. Moreover, VR allows researchers to design experiences with full flexibility; for example, they can create transitions from narrow to vast environments, and content that would be difficult or impossible to access in real life.

Although previous research has provided valuable insights, significant gaps remain in our understanding of how different factors interact to elicit awe and how it is physiologically manifested in the body. For instance, research comparing awe elicitors has shown stronger emotional responses to natural landscapes than to human-made structures [3]. Transitions from narrow to vast environments are theorized to enhance awe by increasing surprise and the perception of vastness [6], and may affect both subjective experiences and physiological markers [57]. Cultural background also plays a significant role: awe is more closely linked to spiritual experiences in some Eastern societies, while Western interpretations often emphasize achievement or moral beauty [38]. While individual aspects of awe have been explored – such as awe in VR [10], physiological responses in immersive settings [9], and cultural differences using non-immersive media [38] – these factors have rarely been examined in combination. In particular, the role of transitions in shaping awe experiences remains underexplored. By focusing on isolated variables, existing research leaves a gap in understanding how these dimensions interact. To address these gaps, our study offers the following **contributions**:

- Establishing the effectiveness of awe-inducing scenes when presented in VR.
- Clarifying the relationship between awe and presence.
- Providing insights into the relationship between skin conductance, respiration patterns, and self-reported awe in immersive VR settings.
- Identifying how narrow-to-vast transitions correlate with physiological responses elicited in immersive VR.
- Investigating the effectiveness of the VR experience in eliciting awe in people from Germany, Japan, and Jordan.
- Replicating the investigation of how personality traits affect awe experiences in VR.

Building on these contributions, we designed a set of 10 VR scenes, including both awe-inspiring and neutral scenarios, across abstract, nature, and human-made environments. We aim to enhance the understanding of awe experiences in immersive settings by examining self-reported awe ratings as well as physiological markers, such as skin conductance and respiration. Additionally, we explore the influences of country of origin on awe experiences by involving participants from German, Japanese, and Jordanian

backgrounds. Finally, given the theoretical importance of perceived vastness in eliciting awe, we used stimuli containing transitions from narrow to vast views, to investigate their influence on the overall awe experience.

## 2 RELATED WORK

### 2.1 Definition of Awe

For defining awe, most psychological models agree on two core appraisal components: perceived vastness and a need for accommodation, the latter referring to the cognitive effort required to integrate the experience into one's worldview [28, 8]. Vastness can be perceptual, such as a wide natural landscape, or conceptual, such as encountering a complex idea [8]. Additional appraisals can "flavor" awe, resulting in nuanced subtypes: awe mixed with fear (e.g., the sublime), aesthetic awe (elicited by beauty), admiration (in response to ability), moral elevation (inspired by virtue), and supernatural awe (evoked by the seemingly impossible) [28, 31, 40]. Early philosophical and psychological writings emphasized the fearful aspect [23, 27], while more recent definitions highlight feelings of wonder, reverence, and connection [39, 49].

Awe is widely regarded as a transformative emotion. Studies link awe to prosocial behaviors, increased connectedness, a diminished focus on the self ("small self"), expanded time perception, and enhanced ecological awareness [13]. These effects are reflected in the structure of measurement tools like the AWE-S scale [67]. Beyond its affective qualities, awe is also seen as a driver of curiosity, learning, and conceptual change [63, 39], making it particularly relevant for psychological and educational research.

### 2.2 Eliciting Awe

VR is increasingly recognized as an effective medium for eliciting awe. Immersive VR environments reliably evoke stronger awe responses compared to traditional media such as 2D videos or images [13, 66]. The design of awe-inducing VR scenes is generally guided by findings from traditional awe research, particularly the importance of vastness, novelty, and aesthetic appeal [28]. Commonly explored awe-inspiring VR scenes include natural landscapes such as mountains, forests, waterfalls, and underwater environments, often chosen for their intrinsic vastness and aesthetic beauty [10, 46, 44, 59, 12, 47, 44]. Human-made structures, such as cathedrals or ancient ruins, are also commonly used [25, 46]. One specifically notable example is the *Overview Effect*, where observing Earth from space consistently elicits profound awe [20, 66, 13, 59, 60, 37].

Neutral or mundane environments often serve as control conditions. Examples include simple naturalistic settings [10, 44], an empty apartment [12], and an abstract empty space with a gridline floor [44]. Ensuring these neutral scenes do not inadvertently contain awe-inspiring elements remains a challenge because even subtle features can unexpectedly evoke aspects of awe, making it difficult to accurately measure the effects of the intended awe-inducing scenes.

Given these challenges, there is a need for carefully designed neutral control scenes alongside diverse awe-inducing environments, to further clarify VR's potential in eliciting awe. Additionally, abstract scenes that do not contain cultural connotations should be explored.

### 2.3 Awe and the Sense of Presence

Presence, commonly defined as the subjective sense of "being there" in a virtual environment, comprises spatial presence, involvement, and experienced realism [56] measured for example with the Igroup Presence Questionnaire (IPQ) [51]. Higher presence is generally associated with more intense emotional experiences, including awe [4, 5, 9].

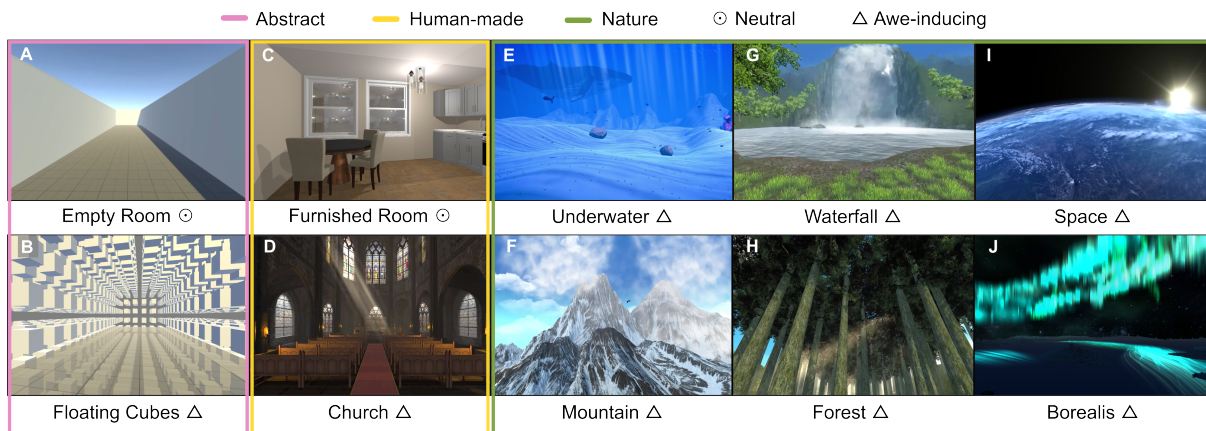


Figure 2: Scenes used in the study. Environmental type (abstract, human-made, nature) visualized with colors. Two scenes are designed to be neutral (A, C, marked with  $\odot$ ), eight scenes are designed to be awe-inducing (B, D-J, marked with  $\triangle$ ).

Evidence suggests a strong relationship between presence and emotional intensity, indicating that higher presence is connected with increased awe [4, 17]. For example, studies found that elements that increase the sense of presence – like thermal stimuli [34] or using first-person perspective instead of third-person perspective [41] – led to greater feelings of awe. However, other findings show no significant difference in reported presence between awe-inspiring and mundane VR stimuli, proposing instead that awe may predict presence, but presence alone does not necessarily predict awe [26]. These mixed outcomes suggest the relationship between awe and presence could be unidirectional and context-dependent.

Given the conflicting results and complexity of this interaction, further exploration is needed. Clarifying whether awe consistently enhances presence or vice versa, especially by comparing awe-inspiring to neutral VR scenes, remains an important area for research.

#### 2.4 Physiological Markers of Awe

Awe is associated with a range of physiological responses, many of which reflect heightened emotional arousal. In immersive VR settings, these responses can be particularly pronounced [9, 46]. Commonly measured markers include heart rate variability (HRV), SCR, SCL, respiration rate, pupil dilation, and somatic responses such as goosebumps [62, 30, 54]. Increases in SCR and HRV typically indicate greater arousal during awe experiences [62]. At the same time, awe has also been associated with decreased respiration rate and increased respiratory sinus arrhythmia, reflecting a calm yet engaged physiological state [21, 62]. Somatic markers like goosebumps have been linked to self-reported awe, especially when users have personal agency in exploring the virtual environment [46]. Importantly, physiological reactions to awe also differ based on the emotional tone of the stimulus. Positive awe, triggered by beautiful or serene stimuli, is linked to parasympathetic activity and relaxation. In contrast, negative or threatening awe is associated with sympathetic arousal and heightened alertness [21, 62].

These findings underscore the complexity of physiological markers in awe, indicating a need to further understand how different awe stimuli in VR uniquely influence physiological reactions.

#### 2.5 Relevance of Vastness for Eliciting Awe

Perceived vastness is widely regarded as one of the core triggers of awe [28]. In VR studies, spatial vastness has been shown to be especially effective [64, 65]. Shifts from enclosed to expansive spaces, or from narrow corridors to open vistas, often enhance the feeling of awe by creating a moment of surprise and disorientation that prompts mental accommodation [28, 1].

This is also reflected in physiological responses, as shown by a study analyzing time-series data changes in SCR and pupil diameter during awe experiences, particularly during narrow-to-vast transitions [62]. Another study found a decrease in SCR accompanied by an increase in SCL before versus after a narrow-to-vast transition [57]. Given these promising findings, including narrow-to-vast transitions in stimuli may be crucial for eliciting awe.

#### 2.6 Differences between Countries in Experiencing Awe

Where someone is from significantly influences how awe is interpreted and experienced. Studies show clear differences between individualistic (e.g., Western) and collectivistic (e.g., East Asian, Middle Eastern) societies [7, 2]. In individualistic societies, awe is often self-focused, emphasizing personal achievements or intellectual revelations [7, 2]. These societies tend to attribute awe to personal agency, aligning with their emphasis on independence and control [33]. For instance, individuals often report feeling empowered during awe experiences rather than overwhelmed [2]. In contrast, collectivistic societies frame awe as a relational or situational emotion tied to external agents like social relationships, spiritual forces, or natural phenomena [2, 33]. Japanese people frequently distinguish between positive awe (e.g., inspired by natural beauty) and threat-based awe (e.g., existential vulnerability) [38], reflecting cultural values such as harmony with nature and impermanence. This distinction is deeply rooted in Buddhist and Shinto philosophies emphasizing transience and interconnectedness [15]. Similarly, people in Iran often link awe to spiritual practices and collective rituals emphasizing unity and reverence for higher powers [48]. Cross-cultural studies highlight both universal patterns and cultural nuances in awe experiences. While the “small self” effect – diminished self-focus – is observed universally during awe experiences, its magnitude, and content vary across cultures [29, 2]. Physiological responses also differ; for example, Chinese participants report greater fear during awe compared to Americans [58], and nonverbal awe expressions vary across countries (e.g., open-mouthed lip puckers in India vs. widened eyes in the U.S.) [14].

Given these cross-cultural differences, we find it interesting to explore how awe is experienced specifically by individuals from countries that have received limited attention in previous research. Population samples from Germany, Japan, and Jordan provide an opportunity to investigate diverse contexts, including environmental and religious influences, while also comparing individualistic and collectivistic perspectives.

## 2.7 Awe experience and Personality

Personality traits shape how individuals experience emotions, including awe. A widely used model to describe personality is the *Big Five* [22], which includes the facets of *Openness to Experience*, *Conscientiousness*, *Extraversion*, *Agreeableness*, and *Neuroticism*. Among these, *Openness to Experience* has consistently been linked to awe. This trait describes a tendency to seek novelty, appreciate aesthetics, and engage with complex or unconventional ideas. Research shows that individuals high in *Openness* report more frequent and more intense awe experiences [53, 55]. One study found that dispositional awe was most strongly correlated with self-rated *Openness* among all Big Five traits [53]. Other research showed that this trait can predict emotional reactions to awe-eliciting stimuli such as space imagery and music [55]. This link was replicated in a Chinese sample, suggesting the relationship is consistent across several countries [18].

However, existing studies have primarily used non-immersive stimuli such as videos or music. It remains an open question whether these findings generalize to immersive awe experiences in VR. Investigating how personality traits, especially *Openness to Experience*, are related to awe in VR can help clarify individual differences in emotional responsiveness to immersive environments.

### 3 RESEARCH QUESTIONS

To address the gaps in research, we formulated the following research questions:

- RQ1:** How effective are awe-inspiring VR scenes in eliciting the experience of awe compared to neutral scenes?
- H1.1: Awe-inspiring scenes will elicit significantly higher levels of awe compared to neutral scenes.
- H1.2: Participants will report a greater sense of presence in awe-inspiring scenes compared to neutral scenes, and this increased presence will be positively correlated with the level of awe experienced.
- RQ2:** What is the relationship between physiological responses (skin conductance and respiration rate) and the self-reported experience of awe?
- H2.1: There will be a positive correlation between SCR and self-reported awe levels, indicating that higher number of SCR reflects greater emotional arousal associated with awe.
- H2.2: Changes in respiration rate will correlate with self-reported awe, suggesting that a lower respiration rate is indicative of a deeper awe experience. Additionally, the combination of increased SCR and decreased respiration rate will serve as a strong predictor of high self-reported awe.
- H2.3: In awe-inspiring scenes with a transition from a narrow to a vast view, this transition phase elicits significantly higher physiological responses than the rest of the scene due to the dramatic change.
- RQ3:** How do individual and country differences (German, Japanese, Jordanian) influence the experience and physiological responses to awe-inducing stimuli?
- H3.1: Country of origin will influence the self-reported experience of awe and physiological manifestation, with variations reflecting cultural values and norms related to different types of awe-inspiring stimuli.
- H3.2: Personality traits will influence the self-reported experience of awe and physiological manifestation, specifically with the trait *Openness to Experience* being positively correlated with high self-reported awe.

Table 1: Measures used in the study

Measure	How	Hypothesis	Variable Type
Self-reported awe	AWE-S	H1-3	Dependent
Self-reported presence	IPQ	H1	Dependent
SCR	GSR sensor	H2	Dependent
SCL	GSR sensor	H2	Dependent
Respiration rate	Respiration sensor	H2	Dependent
Openness to Experience (Personality)	TIPI	H3	Independent
Nationality (Germany, Japan, Jordan)	Demographic question	H3	Independent

## 4 USER STUDY

### 4.1 Participants

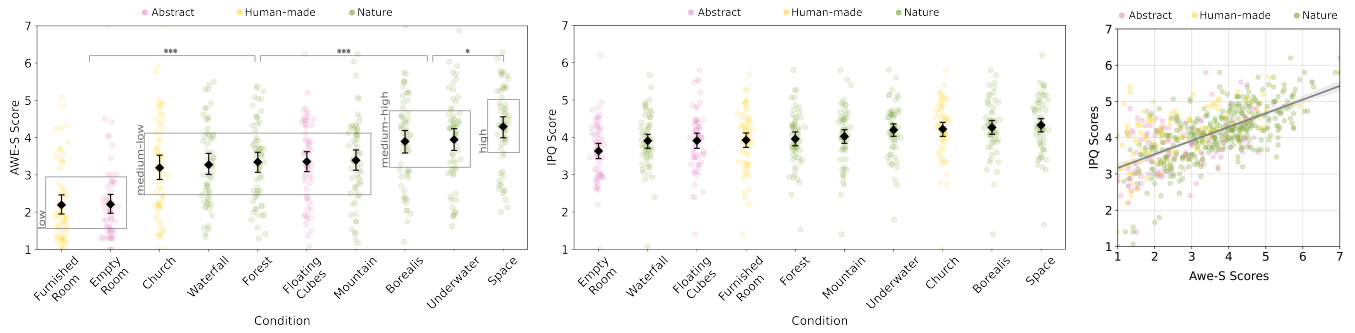
Sixty-two volunteers participated in the study (18 female, 44 male, aged 18-64). They were recruited from three universities in Jordan (20 participants, 4 female, 16 male), Japan (21 participants, 5 female, 16 male), and Germany (21 participants, 9 female, 12 male). One participant withdrew from the experiment due to motion sickness. This experiment was approved by the local institutional review board.

### 4.2 Experimental Design

We employed a mixed-design approach. The independent variables were personality (assessed via TIPI [22]), country of origin (Germany, Japan, Jordan), and VR scenes (10 scenes, including 2 human-made, 6 nature, 2 abstract). Dependent variables included self-reported awe (AWE-S [67]), presence (IPQ [51]), and physiological measures (skin conductance, respiration), all analyzed within-subjects for scene comparisons and between-subjects for individual influences. The order of the 10 scenes was counterbalanced: Each participant was presented with a different order, using Latin Squares to ensure that all scenes appeared equally often in each position. For every group of 10 participants, a unique 10×10 Latin Square was generated, resulting in fully counterbalanced orders across all participants.

### 4.3 Measures

Table 1 lists all measures including which hypothesis it was used for. Awe was self-reported after each stimulus using the AWE-S questionnaire [67], and presence was reported with the Igroup Presence Questionnaire (IPQ) [51]. Skin conductance was measured with a Gtec *g.GSRsensor*<sup>2</sup> sensor sampled at 10 Hz, placed on the middle and ring fingers of the non-dominant hand. The non-dominant hand was chosen to potentially reduce noise in the measurements as it is used less frequently. A TerniMed Nasal/Oral Thermistor respiratory flow sensor was placed between the nose and mouth to measure respiration with a sample rate of 10 Hz. Physiological data were baseline corrected. We selected GSR and respiration because prior work on awe-related autonomic responses has found these markers promising [54, 21]. Pupil dilation was not used due to scene-dependent brightness confounds (e.g., *Borealis* vs. *Mountain*), and heart rate/HRV was deprioritized given previous null findings for awe-specific effects [41]. Images of the sensors are shown on the left in Figure 1. All participants completed the Ten Item Personality Inventory (TIPI) questionnaire [22] assessing their personality, and a demographic questionnaire assessing age, gender, nationality, dominant hand, previous VR experience, and current well-being.



(a) Scatterplots with mean values and error bars representing confidence intervals (CI = 95%) of AWE-S scores for each scene. Environmental groups – abstract, human-made, nature – visualized with color. Post hoc pairwise t-test revealed four groups that are visualized with gray frames: low, medium-low, medium-high, and high awe. Each member of one group has a significant difference from each member of another group, but not towards a member of its own group.

(b) Scatterplots with mean values and error bars representing confidence intervals (CI = 95%) of IPQ scores for each scene. Environmental groups – abstract, human-made, nature – visualized with color.

(c) Correlation plot showing the relationship between AWE-S scores (awe) and IPQ scores (presence). Environmental groups – abstract, human-made, nature – visualized with color.

Figure 3: Results from Hypothesis 1 regarding self-reported AWE-S scores measuring awe and IPQ scores measuring presence.

Table 2: Description of scenes and transitions.

Scene	Fig. 2	Start - Narrow	End - Vast
Empty Room	A	Simple corridor with wiregrid floor	No transition
Floating Cubes	B	Narrow staircase	Large open space with floating cubes
Furnished Room	C	Furnished Apartment	No transition
Church	D	Entry hall	Church interior
Underwater	E	Area enclosed by sand dunes	Open underwater landscape with a passing whale
Mountain	F	Trail enclosed by mountains	Wide mountain panorama
Waterfall	G	Forest trail with dense trees	Scenic viewpoint of a waterfall
Forest	H	Forest trail with dense trees	Forest clearing with Redwood trees
Space	I	Narrow space station corridor	Panoramic view of Earth
Borealis	J	Wooden log cabin interior	Open sky illuminated by Northern Lights

#### 4.4 VR Stimuli and apparatus

10 VR scenes depicting abstract, human-made, and nature environments (see Figure 2) were used as stimuli. Eight of the scenes were designed to elicit high awe (scenes B, D-J), while two were designed to elicit low or no awe (A, C). All high-awe scenes followed the same schemata: the participants start in a narrow area and, while exploring the scene, transition into a vast area to amplify perceived vastness and awe. Table 2 includes descriptions of the narrow and vast areas of each scene. The geometric complexity of the scenes varied but was not controlled: *Church* ~64M triangles, *Forest* ~4.5M, *Waterfall* ~3.5M, *Mountain* ~2.2M, *Borealis* ~1.4M, *Furnished Room* ~1.2M, *Underwater* ~786k, *Floating Cubes* ~200k, *Space* ~5k, *Empty Room* ~2.6k. The visual stimuli are complemented with auditory stimuli, e.g., wind sounds in the *Mountain* scene or organ music in the *Church* scene. The VR scenes were created using Unity 2021.3.6f1. Participants experienced the stimuli through a Meta Quest 2 HMD (Refresh Rate: 90Hz, Resolution: 1800 × 1920 pixels per eye) and wore noise-canceling headphones.

#### 4.5 Procedure

Participants were seated at a desk in front of them and received an explanation of the experiment before they signed a consent form. Afterward, they wore the biosensors and the VR HMD. At the beginning of the VR experience, participants answered the demographic and TIPI questionnaires. All questionnaires were completed in VR without removing the HMD. They experienced one scene at a time, exploring each scene for two minutes. The participant navigated with smooth translation and rotation using the thumbsticks on the VR controllers. To ensure consistent exploration, participants received standardized navigation instructions. Scenes were designed with natural movement paths, environmental boundaries, and invisible walls to guide exploration. After each scene, participants completed the AWE-S and IPQ questionnaires. To ensure participant comfort and mitigate motion sickness, regular check-ins were conducted throughout the session to assess participant well-being and offer breaks as needed. Many participants chose to take small breaks between scenes, removing the HMD.

### 5 ANALYSIS AND RESULTS

All reported p-values were Bonferroni corrected for multiple comparisons within each hypothesis. Before each analysis, we verified all statistical assumptions and chose the appropriate parametric or non-parametric tests accordingly. To confirm that the counterbalancing worked and indeed there were no order effects, a repeated measures ANOVA was used ( $F(9,468) = 0.435, p = 0.916$ ). Visual analysis of mapped positional tracking data confirmed similar navigation patterns across participants. A comprehensive summary of all statistical tests, including p-values, effect sizes, confidence intervals, and normality test results, is provided in the supplementary materials. All analysis scripts will be made publicly available upon publication at <https://github.com/melissasteini/TheAwesomeSpectrum>.

#### 5.1 H1. Awe and Presence across VR Stimuli

H1.1. A repeated measures ANOVA revealed significant differences in AWE-S scores between the 10 scenes ( $F(5.989, 347.387) = 58.999, p < .001, \eta^2 = 0.246$ ). Visual analysis of the error bar plots (see Figure 3a) led us to the assumption that the stimuli can be classified into four groups. Pairwise t-test post hoc analyses confirmed this assumption – each member of one group has a significant difference to each member of another group - but not towards the members of

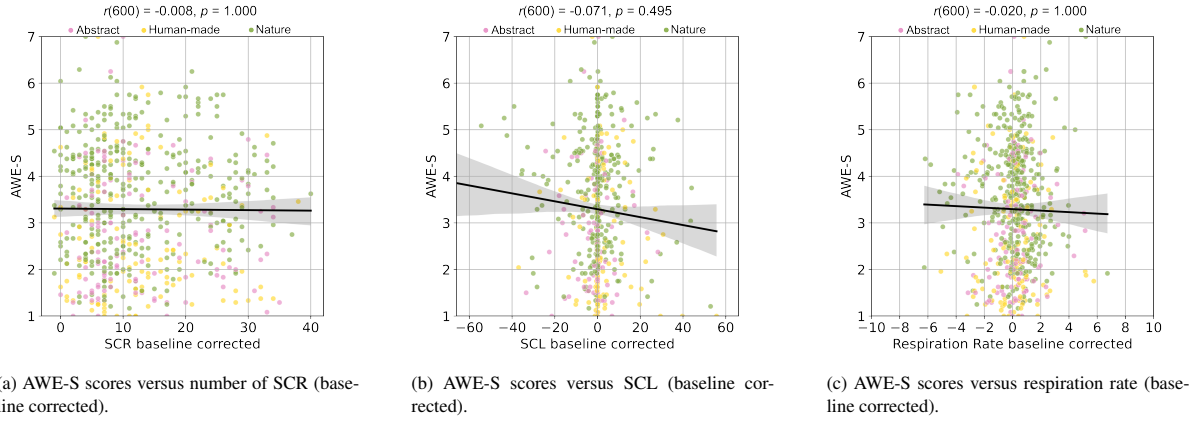


Figure 4: Correlation plots between AWE-S scores and physiological measures during each stimuli experience. Pearson regression is visualized as a black line, with the numerical correlation at the top.

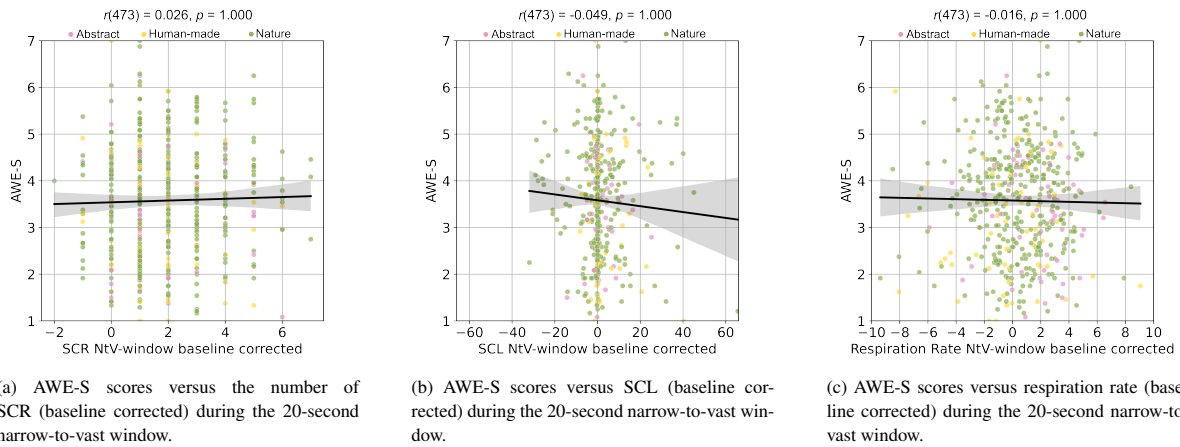


Figure 5: Correlation plots between AWE-S scores and physiological measures during the 20-second window around the narrow-to-vast transition in each awe-inspiring stimuli experience. Pearson regression is visualized as a black line, with correlation results at the top.

its own group. In a direct comparison between neutral and awe-inspiring stimuli, a paired samples t-test confirmed that awe-inspiring scenes scored significantly higher AWE-S scores than neutral scenes ( $t(61) = -12.657, p < .001, d = 1.41$ ). Additionally, a repeated measures ANOVA comparing abstract, human-made, and nature stimuli showed a significant difference in AWE-S scores between the environmental groups ( $F(1.612, 98.336) = 12.437, p = 0.006, \eta^2 = 0.034$ ). Neutral scenes (*Empty Room*, *Furnished Room*) were excluded from environmental-type comparisons to avoid confounds. Post hoc pairwise t-test revealed that the nature stimuli group has higher AWE-S scores than both the human-made ( $t(61) = -3.935, p = 0.021$ ) and abstract groups ( $t(61) = -5.414, p < .001$ ). As mentioned, the nature stimuli were overrepresented in the sample ( $N_{nature} = 6, N_{abstract} = 1, N_{human-made} = 1$ ).

H1.2. A repeated measures ANOVA on the IPQ scores across stimuli, with a Greenhouse–Geisser correction applied due to a violation of sphericity ( $W = 0.208, p < .001$ ), showed a significant effect ( $F(6.913, 400.928) = 13.375, p < .001, \eta^2 = 0.069$ ). Post hoc pairwise t-test comparisons indicated a ranking of stimuli (see Figure 3b): the *Empty Room* scene elicited the lowest while the *Space* scene elicited the highest sense of presence. Moreover, a paired t-test comparing neutral with awe-inspiring scenes showed that awe-inspiring scenes elicited a significantly greater sense of presence ( $t(61) = -5.830, p < .001, d = 0.474$ ). A Repeated measures

ANOVA comparing presence in the abstract, human-made, and nature stimuli was also significant ( $F(1.445, 88.142) = 10.366, p < .001, \eta^2 = 0.031$ ), post-hoc pairwise t-test shows that nature environments elicit a higher sense of presence than both other groups. Finally, a Pearson correlation analysis revealed a significant positive correlation between AWE-S and IPQ scores across all conditions ( $r(618) = 0.624, p < .001$ ) (see Figure 3c).

## 5.2 H2. Physiological Responses and Self-Reported Awe

First, the physiological data were preprocessed. Both the respiration and skin conductance signals were synchronously recorded throughout the experiment. A 10-second black screen preceded each scene and was used to record baseline physiological activity. Respiration data were denoised using the *biosppy* method of the Python NeuroKit2 library[32]. Skin conductance data were smoothed using a two-pass moving average filter with a window size of 10 samples. After denoising, baseline correction was applied. The skin conductance signal was then decomposed into its tonic and phasic components using NeuroKit2’s *eda\_process* function. The mean values for respiration rate, SCR, and SCL were also calculated using NeuroKit2 functions.

H2.1-H2.3. Pearson’s correlation analysis revealed no significant relationships for any of the physiological measures (SCR, SCL and respiration rate) and AWE-S scores, as indicated in Figure 4. Similarly, no significant correlation was found in physiological

measures and AWE-S scores in the narrow-to-vast transition period (20-second window), as indicated in Figure 5. Moreover, we conducted a time-locked analysis around the narrow-to-vast transition. For each awe-inducing scene, we compared the number of skin conductance response (SCR) peaks in the 10-second window before and after the transition using paired-samples t-tests. Aggregating across all awe-inducing scenes (by averaging per participant), no significant difference in SCR peaks was found between pre- and post-transition windows ( $t(61) = -0.16, p = 1.000, d = 0.02$ ). Looking at the pre- and post-transition per individual scene, also no significant differences were found.

### 5.3 H3. Individual differences in the Awe experience

H3.1. A one-way ANOVA comparing mean AWE-S scores (for each participant the mean overall scenes) between the three population samples (German, Japanese, and Jordanian) was significant ( $F(2, 59) = 6.86, p = 0.044, \eta^2 = 0.189$ ). Post hoc Tukey HSD tests revealed that the German group reported significantly lower AWE-S scores than both the Japanese and Jordanian groups (see Figure 6a). Additionally, we looked at the three environmental groups to see if there is a type of scene that elicits stronger differences between the population samples (see Figure 6b):

- **Human-made stimuli:**  $F(2, 56) = 7.50, p = 0.027, \eta^2 = 0.211$ ; Germans scored significantly lower AWE-S scores than Jordanians.
- **Nature stimuli:**  $F(2, 56) = 6.27, p = 0.073, \eta^2 = 0.183$ ; Germans scored slightly lower than Japanese.
- **Abstract stimuli:**  $F(2, 56) = 5.59, p = 0.128, \eta^2 = 0.167$ ; No significance.

A Kruskal-Wallis test indicated significant differences between population samples in physiological responses for SCR ( $H(2) = 77.14, p < .001$ ). Dunns' post hoc analyses revealed that the German sample showed significantly higher SCR compared to the Jordanian sample. There were no significant differences between populations in SCL and respiration rates.

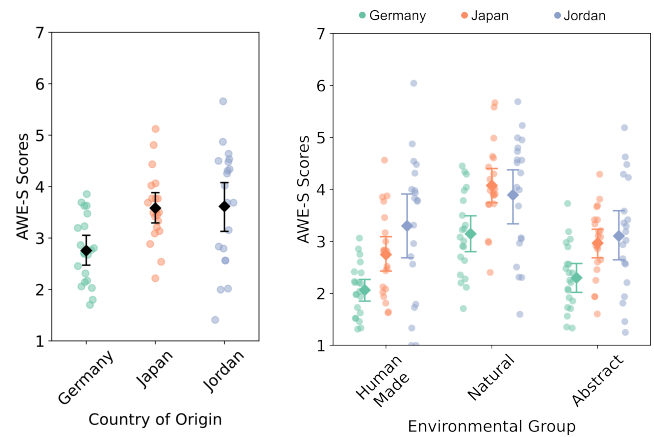
To explore the combined relationship between awe, nationality, and physiological responses, linear mixed-effects models were conducted for SCL, SCR, and respiration rate. All models were estimated using maximum likelihood (ML) via the `mixedlm()` function in the `statsmodels` Python package[52] and run three times to allow all pairwise comparisons. No significant effects were found for SCL or respiration rate. For SCR, results replicated the earlier group comparisons: the Jordanian group showed significantly lower SCR than both the German ( $z = -3.07, p = .002$ ) and Japanese groups ( $z = -2.66, p = .008$ ); no other effects or interactions reached significance.

H3.2. Spearman's correlation analyses were used to examine the relationship between the personality trait *Openness to Experience* (as measured by TIPI) and both self-reported and physiological responses. There was no significant correlation between *Openness* and AWE-S scores ( $r(60) = -0.079, p = 1.000$ ). However, analysis of physiological measures showed a negative correlation with *Openness* and SCR ( $r(604) = -0.240, p < .001$ ), while the correlations with SCL ( $r(604) = 0.016, p = 1.000$ ) and respiration rate ( $r(604) = -0.081, p = 0.970$ ) were not significant.

### 5.4 Exploratory Analyses

A t-test comparing AWE-S scores between genders revealed no significant difference ( $t(61) = 0.1, p = 0.894, d = 0.04$ ). No relationship was found between participants' self-reported VR proficiency and AWE-S scores ( $r(60) = -0.059, p = 0.651$ ).

Spearman's correlation analysis did not showed a relationship between triangle count and the IPQ realism subscale ( $r(60) = 0.503, p = 0.138$ ). Triangle count was not controlled for and varied



(a) Mean values and error bars representing confidence intervals (CI = 95%) of AWE-S scores of each population sample (Jordan, Japan, Germany). Germans reported significantly lower scores than both other population samples. (b) Mean values and error bars representing confidence intervals (CI = 95%) of AWE-S scores of each population in the three environmental type groups: abstract, human-made, and nature. Germans reported significantly lower scores than both other population samples, most prominently in the human-made environments.

Figure 6: Results for Hypothesis 3.1 regarding the relationship of self-reported awe with country of origin.

naturally between scenes. Similarly, Pearson's correlation analysis revealed no significant relationship between awe and perceived realism ( $r(60) = 0.375, p = 0.285$ ).

## 6 Discussion

### 6.1 Limitations

This study has several limitations. Due to convenience sampling and possibly a self-selection bias, the sample was primarily university-aged and included more males than females, though gender distribution was consistent across countries. The age distribution was notably skewed, preventing meaningful statistical age analysis. Further, the set of scenes was not balanced in environmental type, including six nature scenes, two abstract, and two human-made. This imbalance was due to prior literature identifying nature as a consistent awe elicitor: we included many environments that were suggested before. Abstract and human-made environments thus came short. Looking at multiple different nature environments, we were able to balance out possible cultural biases for our international sample. However, we acknowledge that including a neutral nature scene would have allowed a more balanced baseline comparison. The aesthetic quality and fidelity of the VR scenes varied, however we did not control this as it was not a focus of our research. Triangle counts range from approximately 2.6k (*Empty Room*) to 64M (*Church*), however, the geometric complexity did not modulate awe ratings. Further, we did not systematically collect qualitative data, such as open-ended responses or interviews, which could have provided deeper insight into participants' subjective experiences and cross-nationality interpretations of the VR scenes.

### 6.2 Eliciting Awe in VR

To answer RQ1, we analyzed self-reported awe in the VR scenes. Our results support H1.1, confirming that VR scenes can elicit varying levels of awe. The 10 tested scenes fell into four distinct intensity groups based on self-reported awe scores. In the lowest category, the two neutral scenes (*Empty Room* and *Furnished Room*), designed to elicit minimal awe, still recorded scores above zero on the AWE-S questionnaire. This highlights the difficulty of creat-

ing entirely neutral VR environments. Subtle aspects, such as spatial openness or visual novelty, may unintentionally contribute to the experience of awe. This observation is consistent with previous work questioning the neutrality of control scenes in VR [44]. For example, features like unexpected textures or subtle depth cues can evoke emotional responses even in scenes intended to be neutral [10]. These results suggest that baseline awe in VR is rarely absent. To improve control conditions in future studies, we recommend more stringent design constraints (e.g., reduced spatial depth, minimal visual salience) and the inclusion of qualitative follow-up questions or sanity checks to validate participants' interpretation of self-report items and confirm the effectiveness of neutral stimuli.

Five of the 10 scenes fell into the second lowest awe group, including commonly used naturalistic environments such as the *Waterfall*, *Forest*, and *Mountain* scenes [46, 10, 44]. The human-made *Church* and abstract *Floating Cubes* scenes also fell into this group. The *Floating Cubes* scene – including a grid of repeating structures – was designed with geometric repetition and spatial disorientation. Its ability to elicit awe is in line with research suggesting that repetition and vast geometric structures can convey a sense of infinity or boundlessness [68], characteristics often associated with awe. Scenes in the second highest awe group include *Borealis* and *Underwater*, supporting existing research validating underwater environments as effective awe stimuli [46] and introducing the depiction of northern lights as a novel awe-eliciting stimulus. These results also align with prior research emphasizing nature as a consistent trigger for awe [66, 20] and raises questions about optimizing abstract and human-made designs to compete with higher ranking awe stimuli depicting nature. However, our stimulus set contained six nature scenes compared to only two human-made and two abstract ones, which limits the strength of any environment-type comparison. Including a broader mix of abstract and human-made environments – particularly from diverse cultural contexts – would balance the design and allow us to assess whether architectural or conceptual stimuli can match the impact of nature.

The highest awe ratings were observed in the *Space* scene. These findings are consistent with earlier work showing that the Overview Effect – viewing Earth from space – is a particularly strong awe elicitor [66, 20]. This scene may evoke awe not only through its spatial characteristics but also through the conceptual vastness and existential perspective-taking [67], which go beyond the perceptual realism of the VR environment.

### 6.3 Awe Correlates with Presence

Addressing RQ1, we looked at presence in the VR scenes and correlated it with self-reported awe. Our results support H1.2 by showing that awe-inspiring scenes elicited significantly higher presence ratings than neutral scenes. Abstract scenes elicited significantly lower presence than nature or human-made scenes. These findings are consistent with prior research suggesting that spatial realism and coherence contribute to a stronger sense of presence [56]. Naturalistic scenes may offer more continuous spatial depth and recognizable environmental cues, while human-made environments such as the *Church* may benefit from cultural familiarity, which has been shown to increase immersion and presence [46]. Design choices, such as perspective, also influenced presence. In our study, participants viewed scenes from a first-person perspective, which prior research has linked to enhanced spatial embodiment and stronger feelings of control and agency compared to third-person perspectives [41].

A positive correlation was found between presence and self-reported awe. This supports the notion that immersive environments may enhance emotional intensity by strengthening the user's sense of presence [4, 17]. Presence is often considered a prerequisite for emotional responses in virtual environments [42, 45] and research suggests that presence can predict awe [26]. However,

our abstract *Floating Cubes* scene – despite its reduced realism – elicited relatively high ratings for both presence and awe. One possible explanation is that emotionally intense or arousing experiences may increase the perceived realism. This aligns with prior findings suggesting that arousal may influence presence by increasing attentional focus and alertness, thereby amplifying the subjective impression of “being there” [19]. Thus, we assume that further research on abstract scenes could enhance our understanding of the relationship between presence and awe.

### 6.4 No Proof of Physiological Manifestation

Addressing RQ2 we analyzed correlations between physiological markers (SCR, SCL, or respiration rate) and self-reported awe. Contrary to expectations outlined in H2.1, we found no significant correlations. These findings differ from prior research that reported physiological measures as reliable indicators of awe [62, 9].

One likely explanation for the lack of correlation is the way physiological and self-report data were temporally aggregated. We computed average SCR, SCL, and respiration rate values over the entire two-minute duration of each scene, and compared them to a single AWE-S score per scene. However, each scene typically included both potentially non-awe-inducing (narrow) and potentially awe-inducing (vast) segments. As a result, scene-level averaging may have obscured short-term physiological changes linked specifically to awe. Prior research suggests that awe unfolds in distinct phases – anticipation (before the transition), revelation (the moment vastness is revealed), and integration (processing the experience afterward) [65] – each of which may involve different physiological signatures. In contrast, self-report measures such as the AWE-S may be disproportionately influenced by the most emotionally salient moments in a scene, even if those moments are brief [28]. This discrepancy between averaged physiological data and peak-focused self-reports may have reduced the likelihood of detecting meaningful correlations.

Addressing this issue, we conducted a focused analysis on the 20-second window surrounding the narrow-to-vast transition, which we assumed would correspond to the peak of the awe experience. This approach was informed by previous studies showing increased physiological responses during spatial transitions [62]. However, even within this targeted window, we found no consistent relationships between physiological markers and awe ratings and no significant increase of arousal between the pre- to post-transition 10 second window. This outcome suggests that awe's physiological expression may be more temporally nuanced than previously assumed. Future studies should consider using higher-resolution time-series analyses to examine short-term fluctuations and phase-specific dynamics in physiological data, rather than relying solely on aggregated metrics across entire scenes.

Another possible explanation lies in the design of the transitions themselves. We hypothesized that the transition window would elicit both awe and a corresponding physiological response, but this was not supported by the data. One factor may be the nature of the transition: participants explored the scene gradually and at their own pace using thumbsticks. In contrast to prior studies using abrupt or scripted transitions [46], our design may have reduced surprise and, with it, physiological arousal.

Research suggests that user control can modulate autonomic responses by increasing predictability and reducing perceived threat [35]. While the agency may support immersion, it may also diminish the element of surprise thought to underlie awe-related arousal. The interaction between agency and surprise in the context of awe remains an open question.

These findings also suggest that static depictions of vastness may be more effective than dynamic transitions in eliciting awe. Scenes like the *Space* appeared to evoke awe through symbolic or conceptual magnitude, independent of motion or progression. In contrast,

dynamic transitions may require additional design features to reliably elicit strong emotional or physiological responses. Interactive elements – such as user-triggered scale shifts or the manual unveiling of panoramic views – may help reintroduce unpredictability while maintaining user agency [46, 10]. Incorporating contrast elements such as sudden light changes or unexpected environmental expansion may also enhance arousal. These approaches are in line with classical theories of the sublime, which emphasize surprise and contrast as key elicitors of emotional intensity [6].

### 6.5 Awe Experience Differs Across Countries

To address RQ3, we compared participants from Germany, Japan, and Jordan with respect to self-reported awe and physiological responses. In line with H3.1, the three population samples showed different reactions to the stimuli. German participants reported significantly lower awe than Japanese and Jordanian participants. Although our study examined differences by nationality, we interpret these results in light of broader cultural frameworks often associated with these national groups. For instance, prior research suggests that in individualistic societies like Germany, awe is often framed as self-enhancing or empowering, potentially diminishing the “diminished self” aspect of the experience [7, 2]. In contrast, collectivistic societies, like Japan and Jordan, tend to associate awe with relational and spiritual dimensions, emphasizing interconnectedness and harmony [2]. These differences were especially evident in response to the human-made environments that both had Western references. For instance, Jordanian participants reported higher awe in the *Church* scene, potentially reflecting the relevance of sacred spaces and associated values of unity and reverence [48]. Japanese participants showed a slight, non-significant tendency toward stronger responses to nature scenes compared to German participants. This may reflect national traditions rooted in Shinto and Buddhist philosophies, which emphasize harmony with nature and appreciation of its beauty [15]. German participants, likely more familiar with Western connoted environments, may have perceived them as less novel. This aligns with previous findings that unfamiliar stimuli tend to elicit stronger awe responses in collectivistic societies [7]. Individualistic norms, which prioritize agency over external reverence, may further contribute to the overall lower awe ratings observed in the German sample [33]. Even scenes designed to have no nationality bias may not be perceived as such by all groups. Prior research has shown that supposedly neutral stimuli can carry cultural connotations and lead to differing interpretations depending on participants’ backgrounds [61].

In the physiological data, Jordanian participants showed significantly lower SCR responses compared to the other groups, despite reporting higher levels of awe. This pattern was confirmed by linear mixed-effects models, which revealed a main effect of nationality on SCR but no significant effects for SCL or respiration, nor any interaction with awe ratings. These results suggest that SCR may reflect general arousal rather than awe-specific processes. This interpretation aligns with prior work indicating that collectivistic cultures may experience awe as calm and externally oriented, whereas individualistic cultures more often associate awe with excitement and arousal [38].

### 6.6 Openness Linked to SCR but Not Self-Reported Awe

To answer RQ3 we looked at the personality trait *Openness to Experience* and its relationship with awe. Contrary to H3.2, we found no significant relationship between *Openness* and self-reported awe. This challenges earlier findings linking *Openness* to heightened awe responses in non-immersive settings [53, 55]. However, a negative correlation was observed between *Openness* and SCR, suggesting that individuals higher in this trait may show reduced physiological arousal during awe experiences in VR. One possible explanation is habituation: individuals who frequently seek out nov-

elty may become less reactive to awe-inducing stimuli, even in immersive environments [69]. This finding supports theories that link *Openness* to increased curiosity and a tendency toward intellectual exploration [16]. In the context of VR, individuals high in *Openness* may engage with vast environments in a more reflective manner, rather than through immediate emotional reactivity. Such engagement may elicit awe through cognitive accommodation – adjusting mental frameworks to integrate complex or novel stimuli [28] – rather than through rapid autonomic responses.

Exploratory analyses also revealed a negative correlation between age and self-reported awe. However, older individuals were underrepresented in our sample. This insight aligns with prior findings that emotional engagement with immersive stimuli may vary across age groups [43]. Future research should investigate how developmental factors, such as a decline in sensory abilities or a shift in emotional priorities, further influence awe of VR experiences.

Beyond the Big Five framework, other traits such as absorption (the tendency to become deeply immersed in sensory or imaginative experiences) may provide further insight. Although not included in our current analysis, prior studies suggest that individuals high in absorption tend to report stronger awe responses in immersive settings [64]. Future work incorporating both *Openness* and absorption may help clarify how different personality traits shape subjective and physiological aspects of awe in VR.

## 7 CONCLUSION

This study examined the experience of awe in VR across different types of environments, countries, and individual traits. Our findings confirm that awe-inspiring VR scenes elicit higher self-reported awe and presence than neutral scenes. However, designing neutral stimuli remains challenging, as even minimal design features can unintentionally evoke awe. Although presence was positively correlated with awe, physiological measures such as skin conductance and respiration rate did not show consistent associations with self-reported awe. These findings challenge the assumption that awe can be reliably measured by autonomic responses and emphasize instead the role of subjective perception and scene design. We also observed differences across countries. Participants from collectivistic societies reported higher levels of awe, particularly in response to unfamiliar or symbolic stimuli. This suggests that cultural context plays a significant role in shaping awe experiences and should be considered in future VR applications and studies. Furthermore, while *Openness to Experience* did not correlate with self-reported awe, it was negatively associated with physiological arousal, pointing to potential differences in reflective versus reactive engagement with awe-inspiring content.

While our results contribute to the growing understanding of awe, they also emphasize that it is a complex and multidimensional phenomenon. Its measurement and elicitation depend on factors including presence, scene design, cultural background, and individual differences. Future research should aim to improve the temporal precision of physiological data collection, include broader personality traits (such as absorption) and consider the design of transitions and agency in VR environments to more effectively capture the dynamics of awe.

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