Jump Cut Effects in Cinematic Virtual Reality: Editing with the 30-degree Rule and 180-degree Rule

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ABSTRACT

Virtual reality (VR) is an immersive medium that offers users a unique opportunity to experience a digital environment realistically. As the demand for VR content continues to grow, the importance of effective VR editing techniques becomes increasingly apparent. This paper is a pioneering work investigating the effects of jump cuts on the viewer's sense of presence, viewing experience, and edit quality in cinematic VR. Specifically, this work focuses on using the 30-degree and 180-degree rules in VR editing to minimize the adverse effects of jump cuts. We conducted a user study with thirteen participants, who watched nine different VR edits and completed a survey for each edited video. Our results indicate that employing the 30-degree and 180-degree rules in VR editing can significantly improve the sense of presence, viewing experience, and edit quality while mitigating the negative effects of jump cuts. We provide valuable insights for VR content creators and editors to achieve more effective and immersive VR experiences.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 INTRODUCTION

Virtual Reality (VR) provides an immersive experience, allowing users to interact in a computer-generated virtual world. As one of the emerging transmedia that carry information, knowledge, and immersive experiences, VR can be regarded as a good candidate for conveying messages.VR applications and relevant research have grown rapidly and enormously since 2016, as technologies, hardware, and content platforms have matured. After significant research efforts and improvements from the industry, VR can now cause emotional and physiological reactions in users, beyond the traditional 2D screen medium [1]. There is a great need for a deeper understanding of this medium and research into VR content creation strategies.

In cinematic VR (CVR) content, a critical component in storytelling is VR editing [2]. VR editing has emerged as one of the challenging scenarios in CVR content creation because it breaks away from traditional filmmaking experiences involving a camera operator and traditional limited framing [3]. Film language refers to conventions and film techniques developed by filmmakers and film theorists for conveying meanings and stories [22]. In a 2D screen-based medium, cinematic contents are made of shots. Continuity editing, specific strategies for creating continuity and discontinuity in film editing based on the needs of the story, has been used widely in the filmmaking industry. Continuity editing provides important decision-making guidelines for filmmakers to determine variables of a shot (position, angle, duration, movement) and how to arrange the shots in a scene to support the storytelling. Among continuity editing guidelines, the 30-degree rule and the 180-degree rule are two common rules to avoid audiences' perceptual distraction, called jump-cut effects. In a 360-degree context and given the user's ability to control the viewing angle, much of the traditional film language seems redundant. The question, therefore, arises of whether the dominant cinematic editing strategy – continuity editing [7] – can be applied to CVR [4].

Researchers and practitioners have tried to answer this question and report positive results on viewers' perception of continuity based on different types of edits [4], having investigated viewers' comfort, sickness, and ability to maintain spatial awareness of dynamic objects in different types of scene transitions [5]. In the theory of continuity editing in cinematic language, when filmmakers attempt to combine scenes or shots to form smooth and coherent storytelling, discontinuity should be avoided to ensure audiences' viewing experiences and the logical consistency of the story [6]. Discontinuity in edits could cause jump-cut effects, which refers to an audience's distraction when watching a video. The jump-cut effects are one of the focuses that creators and editors should consider during the creation process. In most cases, a jump cut should be avoided to ensure the audience's watching experience is smooth and engaged [6, 18]. In some cases, however, filmmakers apply a jump cut on purpose to create a feeling of distraction and interruption among viewers when the storytelling requires it [26].

A jump-cut effect that creates an unavoidable distraction to audiences during their watching experience could be of serious concern for VR content creators and product designers, because it may hinder audiences from immersing themselves in the virtual environment and storytelling. In common filmmaking practice, two core principles exist to identify the jump cut effects: the 30-degree and 180-degree rules [6, 7]. This paper aims to apply these two cinematic conventions to explore and identify jump cuts in VR. In particular, we aim to investigate answers to the following questions:

Q1. Does a jump cut exist in the VR context?

Q2. How does the audience perceive a jump cut in cinematic

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virtual reality (CVR)?

Q3. How does a jump-cut effect affect the audience's watching experience and engagement?

Q4. Does VR editing that avoids jump cuts provide a more engaging viewer experience than those with jump cuts in VR?

2 Related Work

2.1 Continuity Editing in Cinematic Studies and VR

In cinematic studies, movies are often considered a literary form that communicates information to viewers through a communication structure between sender and receiver [25]. Films are made up of shots, with each shot containing different elements of time, space, and action [9]. Filmmakers use various strategies and theories to create an uninterrupted and engaging storytelling experience for their audiences. One such strategy is continuity editing, which involves creating continuity and discontinuity in film editing based on the story's needs [6, 7, 26].

Continuity editing has been rooted in Hollywood filmmaking practice and observed since the 20th century [7]. It is the foundation of modern filmmaking strategies and has influenced various fields, such as games, commercials, and virtual content in theme parks [27]. However, despite being widely used in the industry and taught in filmmaking textbooks, there is limited research on how continuity editing affects perceptions of continuity and discontinuity through a sequence of moving images [4]. One common explanation for continuity editing's success is event segmentation theory [9], which states that our brains segment continuous actions into discrete and meaningful events [8]. This theory has been applied to study the impact of continuity editing in films [9]. Recent studies have also provided data on viewers' perceptions of continuity and discontinuity in VR, based on studies of regions of interest (ROIs) in edits with variables such as time, space, and action aiming to provide valuable guidelines for VR content creation [4]. Serrano et al. [4] adapted the event segmentation theory by Jeffrey Zacks and investigated the relationship between the edits and the perceived event segmentation. Their results have shown that action discontinuity is the primary factor for viewers to perceive the event boundaries in 360° immersive narrative movies. Moreover, the edit, they applied continuity editing in one scene, can successfully maintain a sense of continuity in action in a 360° environment. Both results support the alignment of viewers' perception to event boundaries and continuity between traditional 2D screen-based medium and 360° narrative environment when applying the continuity editing method. Some VR edit datasets have been created with categories of types of edits for studying and analysing viewer behavior [10, 11]. However, these studies' datasets mainly focus on types of transition [10] and edits with scenes with or without clear ROI [11]. The two datasets investigating VR edits focus on editing with two or more scenes. The effect of VR editing within one scene remains underdeveloped, and our study aims to advance the knowledge of VR editing by filling the aforementioned gap.

Edit with Cuts within one scene is one of the most common tools in film editing and storytelling [6, 12]. By varying location, angle, distance to ROI, and camera framing, this method allows viewers to observe the storytelling from different angles and the story's emphasis. Film editing aims to arrange shots in a scene to generate a sequence of shots that presents an engaging viewing flow for audiences. Professionals call such successful edits an "invisible cut" [12]. A jump cut is often quoted as a shot that could break the viewing flow and cause a distraction to audiences [6]. This paper examines the jump-cut effect in VR editing, focusing on rules that have long been established in traditional cinematic language. Our results could provide new knowledge to the well-established theory, and serve as valuable guidelines for VR content creators to edit their VR content.

2.2 Viewing Experience and Flow theory

How can we engage audiences in our created content? This question consistently motivates content creators, inventors, and researchers to innovate methods or techniques to enhance user experience. Film and VR media content creators have the common goal of immersing audiences in the visual environment they create. Based on the flow theory developed by Mihaly Csikszentmihalyi in 1975, users can be fully immersed in an activity when deeply engaged in its performance [13]. Additionally, a flow experience refers to an engaging experience when a participant is fully immersed in an activity and feels forgetting time, fatigue, and everything else but the activity itself, during which participants find the activity "enjoyable and rewarding" [14]. According to Csikszentmihalyi, intense experiential involvement is the defining feature of flow. Some experimental studies have indicated that VR users experience a better perception of streaming and immersion [15]. Some researchers have applied flow theory to evaluate users' engagement to reflect flow experience in applications such as medical training in a VR context [16]. Content creators tend to lead audiences and users to the flow experience [25] through different approaches. However, interruptions or distractions could rapidly influence a user's watching experience and flow experience. Practitioners have attempted to develop methods to avoid audience distraction in different media. For example, while audiences are seated facing the performers in a stage performance, spotlights often lead their eyes to different "scenes" while others are left in shadow. According to the flow theory, human engagement relies on information obtained through different senses and seeing obtains the most significant proportion of information of all the common five senses [13]. A visually-driven distraction may lead to distraction in engagement in the CVR experience. The "invisible cut" goal in film editing reflects the filmmaker's concerns about audiences' viewing flow. To achieve this goal, some film conventions have been based on practice to avoid such possible distractions or interruptions to the viewing experience. An important strategy is to identify and avoid jump cuts. Our study intends to apply filmmaking conventions to identify the jump-cut effect in VR and investigate its potential adverse effect on the audience's viewing experience.

3 Preamble: Jump Cut Effect

The "jump cut effect" refers to the audience's distraction from watching a shot edited due to discontinuity of content, movement, position or time [6]. In cinematic theory, the 30-degree rule and 180-degree rule have often been addressed as two important guidelines regulating continuity editing [6, 17]. Even though the two rules sound similar in applying variations on the camera angle, they have different focuses on identifying the discontinuity or interruptions in the audience's perception. While the 30-degree rule suggests visual similarities could generate jump-cut effects for audiences, the 180-degree rule addresses how inconsistent screen direction could cause jump-cut effects. In the context of a 360° environment, viewers have the freedom to control their viewing angle in most cases and even have the freedom to change their position in some previous CVR works. The important decision-making in VR editing mostly lands on the camera's or viewer's initial angle and position. Hence, our study centers on a thorough investigation of the initial camera angle and viewer position within the VR shots, recognizing their paramount significance in shaping the VR editing process. (Fig. 1)

The 30-degree rule. The 30-degree rule is a filmmaking guideline that recommends having a difference of at least 30 degrees in camera angle when editing two shots of the same subject within a scene. This guideline aims to prevent a jarring effect caused by a jump cut, which occurs when the camera angle difference (CAD) between two shots edited together is too small, leading to a sudden change in the ROI that viewers perceive. On the other hand, having a sufficiently large difference in CAD between shots can create a smoother viewing experience and help to enhance storytelling. When the camera angle

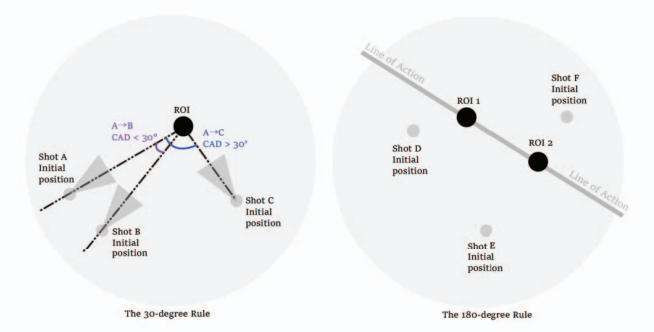

Figure 1: The 30-degree rule: In film-making theory, transitioning from shot A to shot B with a Camera Angle Difference of less than 30 degrees is considered a breach of the 30-degree rule, potentially resulting in a jump cut. Transitioning from shot A or B to shot C, adhering to the 30-degree rule, is achieved because there is a sufficient change in camera angle. The 180-degree rule: The line connecting two ROIs forms "line of action". Transitioning from shot D or E to shot F is considered a violation of the 180-degree rule due to camera positions crossing the "line of action". Conversely, transitioning from shot D to shot E is considered following the 180-degree rule because the camera's positions are maintained on one side of "line of action".

is wide enough, a different meaningful event can be perceived during the edit, leading to more effective storytelling. The 30-degree rule aligns with the event segmentation theory, which suggests that the human brain naturally segments ongoing events into meaningful units based on perceptual and conceptual cues.

The 180-degree rule. The 180-degree rule is a guideline filmmakers use to maintain consistent screen and movement directions for viewers. In the context of editing within a single scene, it is recommended that the audience observes the story from the same side of the scene. Therefore, the camera locations of two shots should be positioned on the same side, and the line that separates a scene into two sides is called the "action line," "line of action," or 180-degree line [6, 17]. This line ensures that camera locations remain on one side instead of crossing over to the other. There are several ways to identify this line, including the movement direction of a subject, the connection of two ROIs, or the direction of a character's gaze [6, 7]. It is suggested that this imaginary line exists between two objects that have some discernible relationship [6]. A noticeable effect audiences perceive from the jump cuts breaking the 180-degree rule or crossing the line is the sudden change of screen direction, character direction, or movement direction.

The 30-degree rule and 180-degree rule have been obeyed and broadly executed in the film industry and have been used as a guideline in filmmaking education. In non-360-degree screen design, filmmakers can apply the 30-degree rule and 180-degree rule to ensure that the audience has a smooth watching experience or to apply jump cut effects to generate the experience of intended distraction and discontinuity as an effect of storytelling [7].

Distance to ROI (DROI). It is another vital variable that should be considered when editing shots in a film. This variable is often used in conjunction with the 30-degree rule to ensure viewers have a more dynamic and engaging viewing experience. In essence, DROI refers to the distance between the camera and the ROI in the shot. It is suggested that filmmakers should try to cut shots with varied DROI together to create a more visually exciting and engaging edit [6, 7]. This is because cutting together shots with different DROI can give viewers greater sense of depth and perspective and alleviate the impact of jump cuts [18]. By incorporating shots with different DROI, filmmakers can create a more visually diverse and engaging sequence that draws viewers in and keeps them engaged with the story. Our study also considers DROI as an essential variable. By analyzing how different DROI values impact viewer engagement and perception of continuity in VR, we aim to provide filmmakers with a more comprehensive understanding of using DROI effectively in their VR edits.

Evaluation of Jump Cuts. A study with 97 participants, conducted by Dan G. Drew and Roy Cadwell in 1985, provided a groundwork on how jump cuts could be perceived in traditional film editing [18]. The participants watch television news edits with the following variations: angle difference as the main effect, distance difference as the main effect, and angle&distance interaction as the main effect, to rate 20 dependent bipolar adjectives. The study reveals that changes in angle, distance, or both could alleviate jump-cut effects. They concluded that changing the distance from further to close-up could make audiences feel more natural, relaxed, informative, and easy to watch compared to the conditions of the high jump cut while changing the camera angle also gained positive results on four scales: real, clear, easy, and reliable. However, they failed to have positive results compared to high jump cut videos by leveraging the interaction of angle and distance.

Tian et al. also applied 30-degree and 180-degree in their experiment design to investigate VR film editing and cognitive event segmentation [19]. They used subjective questionnaires and an EEG-based experiment to evaluate how 30 participants perceived VR film edits. The variations of edits they produced for experiments were based on the definition of continuity from the event segmentation theory [8, 9], which is based on three variations: time, space, and action. Besides edits with the mentioned variations, a continuous animation VR shot without cut was produced as one of the comparing subjects. The key findings landed on lower perceived load and higher immersion for continuous shots compared to the other groups of variations, but no effects were found between other groups. Even though they included two edit variations within one scene as experiment subjects, their application of the 30-degree and 180-degree rule was limited to producing two edits within one scene without focusing on the potential jump cut effect produced from the shots. The result regarding these two edits is more focused on the difference in editing without cut and is not significant to the investigation of VR edit within one scene. Although the above two studies referenced our study's motivations and evaluations, none directly answered how audiences could perceive VR edits within a single scene in VR. Editing multiple shots within one scene is common in traditional filmmaking and visual storytelling. By locating cameras representing different shots in one scene, with variations of angle, distance, time, and lens, audiences can be engaged in stories with different emphases on narratives [6,7]. It is a powerful tool in storytelling and editing and a highlight of employing continuity editing [6, 12]. We believe the exploration of specific directions is essential to the field of VR storytelling and VR editing. No previous study or dataset investigated VR edits and jump cuts within a single scene. To our knowledge, we are the first study to address this unique issue.

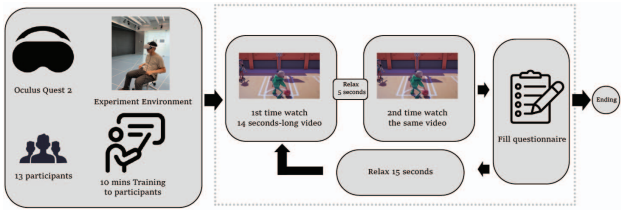

Figure 2: Flow chart of the experiement.

4 METHODOLOGY

The experiment consisted of a set of subjective questionnaires edited based on Igroup Presence Questionnaire (IPQ) [20] and User Experience Questionnaire-Short (UEQ-S) [21].We also employed some descriptive words from a former study on video editing and perception [18]. We filtered out irrelevant and consolidated similar questions from the previous questionnaires to avoid confusing or tiring the experiment participants excessively, eventually achieving a much more concise questionnaire. Therefore, the experiment could measure the sense of presence, viewing experience, and edit quality.

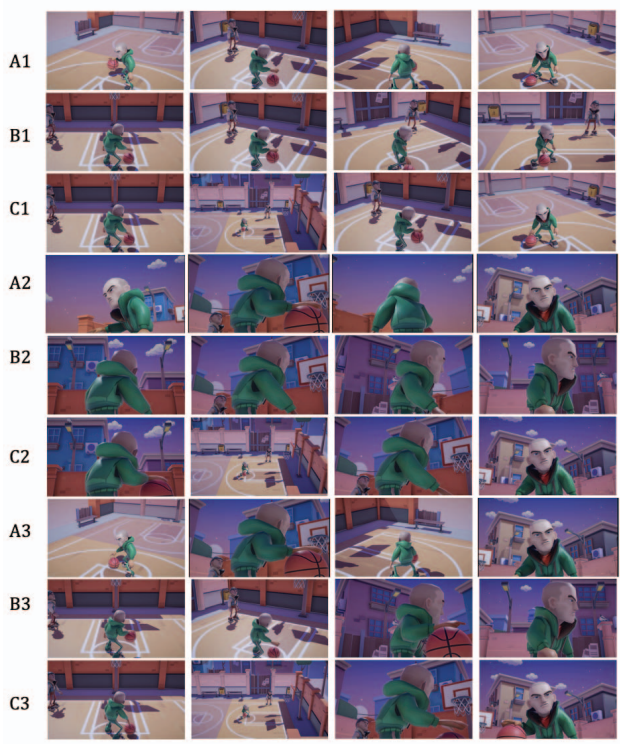

Figure 3: Experimental material. From left to right, it shows the sequence of edits.

4.1 Participants

For this experiment, we recruited thirteen participants ($\bar{M}$=23.5, SD=1.2) from the university. Of these participants, six were male, and seven were female. Before the main experiment, the participants received a brief introduction explaining that they would be watching a clip featuring the opening of a VR story. They were then given approximately 10 minutes to put on the VR headset and perform a visual acuity test, depicted in Fig. 2.

4.2 Scenario

To fulfill the need to apply the 30-degree rule and 180-degree rule to generate VR jump cuts, we designed an immersive animation scene with consistent location, ROIs and animation, which is beneficial to investigate the potential varied effects to audiences with different settings of initial camera or observer's angle while all the other affecting elements remain same. Since our main focus in this study is highly relevant to the original concept of the 30-degree and 180-degree rules based on film convention, the main criteria to design the scene is the clarity of variables in the application of both 30-degree rules (ROI, line of action), we choose to render consistent animation with different camera/observer's angles. The original scene model

Table 1: 3×3 experiment clip list

	Camera location cross Action line (Large angle)	CAD<=30° (Small angle)	CAD >30° & camera location stays same side (Middle angle)
DROI: Long (L)	A1	B1	C1
DROI: Short (S)	A2	B2	C2
DROI L & S Mixed	A3	B3	C3

(.blender) was obtained from sketchfab.com and edited in Unity. The animation scene's description (Fig. 3) is as follows: *In a 360° outdoor basketball court environment, the main character, a man, is clapping basketball, looking at the basketball hoop. A secondary character is standing by the basketball court.*

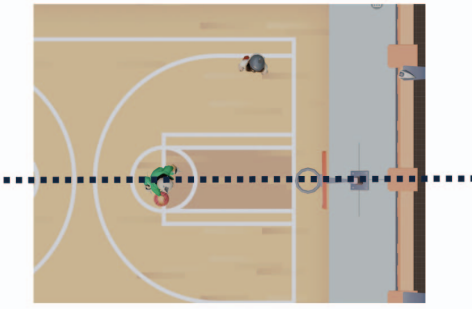

Figure 4: In a basketball court scene, the "action line" connects the main character (ROI1) and the basketball hoop (ROI2).

In this scene, the man clapping basketball is the major ROI. Based on the rules to identify the "action line," the line connects the ROI, and the basketball hoop is the action line that is needed for the 180-degree rule (Fig. 4). As we discussed applying DROI as variables with the two rules, we generated full shots (long DROI) and medium shots (short DROI). A 3×3 experiment is designed with nine different VR edits for user study (Table 1). Each edited 360° video was 14 seconds long, consisting of 4 shots. The video format was encoded with H.264, the resolution for all 360° video was 6000 * 3000, and the frame rate was 30 fps. A program and interface to control playing videos were developed in Unity for the user study. All participants used the Oculus Quest 2 headset to view the VR videos, with a resolution of 1832×1920 pixels per eye and a refresh rate of 120 Hz.

4.3 Procedures

The task sequences of the user study were randomized, where thirteen participants viewed a VR video individually and completed questionnaires after each viewing. To ensure a comprehensive evaluation and avoid the learning effect, we asked the participants to attend two separate sessions on different days, where they viewed a different sequence of VR videos in each session. During each session, participants reviewed four or five videos randomly selected from the experiment settings and had to watch nine videos in the entire study. The evaluation questionnaire was administered after each video review, involving two playbacks. A ten-minute training was conducted for each participant before each session, in which participants were introduced to the instructions to use the VR headset and the overview of the VR video viewing and evaluation task. The order in which the VR videos were presented was randomized for each participant to reduce the effects of order bias. Each user study session was held individually for each participant. The other participants who arrived earlier were asked to wait and relax in another room without being exposed to the study beforehand. The user study was conducted in a university classroom with a capacity of 50, providing enough space and resources to ensure a comfortable and controlled testing environment.

5 Evaluation Results

All participants completed 16 core 7-scale questions and three additional yes/no questions investigating the perceived discontinuity or interruption arising from the film flow [1].

Our study employed mixed-effects modeling and post-hoc analyses to examine the 7-scale questions. Mixed-effects models are widely used in behavioural research to account for the nested structure of data, where observations are nested within subjects or groups. This model enables the integration of both fixed and random effects, offering greater flexibility in modeling individual differences and accounting for correlations within the data. To investigate the significance of specific effects and explore any significant interactions observed in the mixed-effects models, we performed post-hoc analyses using pairwise comparisons. Bonferroni correction was employed to control for type I errors when adjusting for multiple comparisons. η_p^2 is employed as the effect size to indicate the strength of the relationship between two variables [2].

For conveniently interpreting the data analysis (Fig. 5 - 7, we categorize variables related to angle into *Large*, *Small* and *Middle*. *Large* angle represents edits with CAD more than 180 degrees, which are the edits breaking the 180-degree rule and potentially jump cuts. *Small* angle represents edits with CAD smaller than 30 degrees, which are the edits breaking the 30-degree rule and potentially jump cuts. The *Middle* angle indicates the edits with CAD bigger than 30° and the camera staying on the same side of the action line and potentially not jump cut.

Table 2: contingency table for the relation between sense of discontinuity and edit type

	Discontinuity noticed	Discontinuity NOT noticed
Edits with Jump cut (A1-B3)	28	50
Edits without Jump cut (C1-C3)	16	23

Table 2 is the contingency table. The χ^2 test indicates no significant relation between the edits type and perceived discontinuity ($\chi^2_{1,117} = .29, p = .59, \phi = .05$). Also, when looking into data for those who perceived the discontinuity, participants didn't feel any difference in the viewing experience ($\chi^2_{1,28} = .57, p = .44, \phi = .14$) but noticed the disrupted film flow ($\chi^2_{1,28} = 7, p < .01, \phi = .5$).

5.1 Presence

Four questions investigate the viewer's sense of presence (**P1** – **P4**). The mixed-effects model has been conducted to analyse the effect of camera angle and distance on the user's presence (NumDF = 2, DenDF = 104). The result reveals that DROI (marked as distance in Fig. 5) has significantly affected both **P1** ($F_{2,104}$ = 10.29, $p < .001$, $\eta_p^2 = .17$) and **P2** ($F_{2,104}$ = 5.64, $p < .01$, $\eta_p^2 = .10$). For the effect of camera angle on the sense of presence, there are no significant results found from the positively correlated questions **P1** and **P2**, but the significant result has been revealed in **P3** ($F_{2,104}$ = 5.56, $p < .01$, $\eta_p^2 = .10$). No significant results are found in **P4**. Fig. 5 shows the post-hoc analysis results for the sense of presence, indicating there is a significant preference for the edits with short DROI over edits with long DROI on **P1** (Estimate = .79, t = 4.50, $p < .001$, $\eta_p^2 = .16$), as well as over edits mixed with short and long DROI on **P1** (Estimate = .49, t = 2.76, $p < .01$, $\eta_p^2 = .07$). **P3** investigates the user's potential not to pay attention to the virtual world. Therefore, the higher scores indicate a potentially lower sense of presence. VR edits with a large angle and crossed action line have significantly affected the sense of presence negatively, compared to edits with a small angle (Estimate = .36, t = 2.27, $p < .05$, $\eta_p^2 = .05$) and edits with a middle angle (Estimate = .51, t = 3.25, $p < .01$, $\eta_p^2 = .09$). A marginal significance exists, revealing that edits with middle angle get a higher score than the edits with a small angle on **P1** (Estimate = .31, t = 1.74, p = .08, $\eta_p^2 = .03$) and **P2** (Estimate = .35, t = 1.96, p = .05).

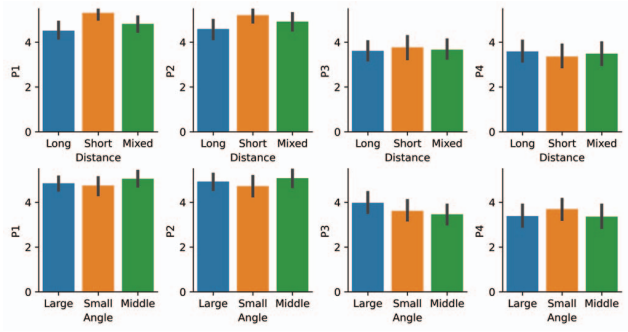

Figure 5: Effect of *Distance* and *Angle* on sense of presence.

From the data collected, we found that the camera distance to ROI, or distance between viewer and ROI in a 360° context, is a vital factor in influencing the user's sense of presence. Both **P1** and **P2** get positive results that viewers feel more "being here" and "present in a virtual world" when they are watching the VR edit, putting them at a closer distance to ROI. The difference between short ROI and long ROI is significant, suggesting that getting closer to ROI could bring a stronger sense of presence while getting further to ROI could bring a weaker sense of presence. The absence of significance shows the effectiveness of applying continuity edit, mixing different DROI, to create a sense of presence. Potential jump-cut effects on a sense of presence have been revealed from **P1** and **P2**, which shows the tendency that edits breaking the 30-degree rule ($CAD <= 30$) gain relatively lower score on the sense of presence than the edits potentially without jump cut (**P1**: p = -.08, **P2**: p= -.05). The significant result found from **P3** ($p < .01$) indicates a potential correlation between viewing jump cuts breaking the 180-degree rule and being easier to be distracted by real-world surrounding. The potential edit without jump cut gains the highest score on **P1** and **P2** with marginally significant results and the lowest score on **P3**, indicating its negative effect on engaging audiences.

5.2 Viewing Experience

Six questions were designed to investigate users' viewing experience, focusing on their subjective feelings about the VR video-watching experience. Mixed-effects model (NumDF = 2, DenDF = 104) analysis has revealed the significant effect of DROI on multiple items related to viewing experience: **Interesting** ($F_{2,104}$ = 6.57, $p < .01$, $\eta_p^2 = .11$), **Exciting** ($F_{2,104}$ = 12.29, $p < .001$, $\eta_p^2 = .19$) and **Liking** ($F_{2,104}$ = 3.08, $p < .05$, $\eta_p^2 = .06$). Post-hoc analysis (Fig. 6) implies that edits with short distance to ROI have been more favoured than edits with long distance on multiple items significantly: **Interesting** (Estimate = .72, t = 3.44, $p < .001$, $\eta_p^2 = .10$), **Good** (Estimate = .46, t = 2.37, $p < .01$, $\eta_p^2 = .05$), **Exciting** (Estimate = .92, t = 4.90, $p < .001$) and **Liking** (Estimate = .56, t = 2.43, $p < .05$). The significant preference for edits mixed distance to ROI over edits with long distance to ROI is revealed on **Interesting** (Estimate = .56. t = 2.70, $p < .01$, $\eta_p^2 = .07$), while the edits with short distance gains significant preference comparing to the edits mixing long and short

[1] Click to view the online questionnaire

[2] Small effect: .01; medium effect: .06; large effect: .14 or higher

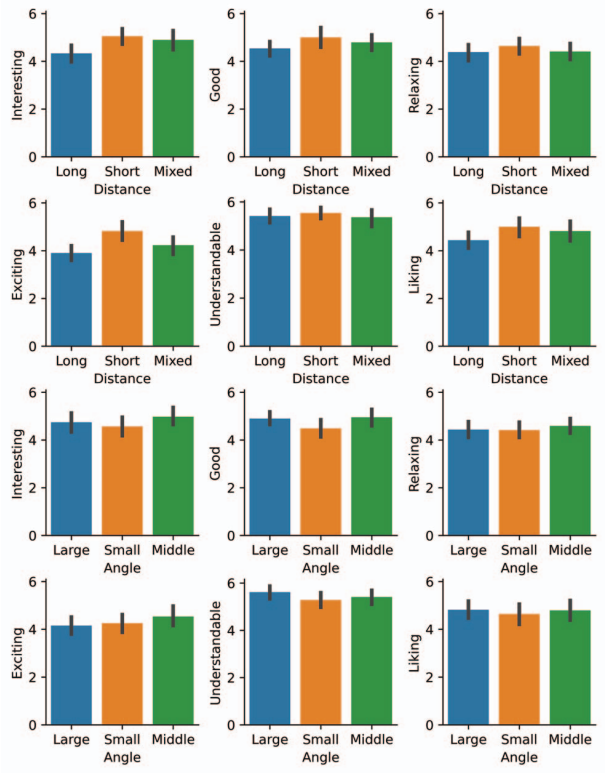

Figure 6: Effect of *Distance* (rows 1 - 2) and *Angle* (rows 3 - 4) on viewing experience

DROI on **Exciting** (Estimate = .59, t = 3.13, $p < .01$, $\eta_p^2 = .09$). For the effect of camera angle to the viewing experience, edits with small angle have negatively affected users' judgement on **Good** than edits with large angle (Estimate = .41, t = 2.11, $p < .05$, $\eta_p^2 = .04$), as well as the edits with middle angle (Estimate = .46, t = 2.11, $p < .005$, $\eta_p^2 = .05$). A significant result reveals that edits with a middle angle get higher scores than edits with a large angle on **Exciting** (Estimate = .38, t = 2.04, $p < .05$, $\eta_p^2 = .04$). Edits with a middle angle also get higher scores than the edits with a small angle on **Interesting** but with marginal significance (Estimate = .41, t = 1.97, p = .05, $\eta_p^2 = .10$).

Distance to ROI seemingly affects the viewing experience, aligning with our findings on the sense of presence. A significant preference from participants for edits with short DROI over edits with long DROI has been found on multiple items: **Interesting** ($p < .001$), **Good** ($p < .01$), **Exciting** ($p < .001$), and **Liking** ($p < .05$), suggesting that edits with closer to ROI could bring more positive view experience than the one with long ROI. However, like findings from the sense of presence, there is no evidence of a positive correlation between the continuity edit mixing different DROI and the positive viewing experience. For the jump cut effect, we found that the edits with CAD smaller than 30° have a negative effect on the user's judgement on the item **Good** with a lower score than edits breaking the 180-degree rule and edits without jump cuts ($p < .05$). VR edits following both the 30-degree rule and the 180-degree rule without jump cuts have more substantial effects for bringing excitement than jump-cut edits breaking a 180-degree rule ($p < .05$). A similar result is also found in measuring **Interesting** that VR edit without jump cuts gets a higher score than a jump cut breaking 30-degree rule but with relatively less significant data result (p = .05). Overall, the effect of angle difference is not as significant as DROI to viewing experience from our study. However, the suggested edit we apply traditional cinematic convention (30-degree rule and 180-degree rule) does offer relatively better viewing experiences on **Interesting** (p = .05) and **Exciting** ($p < .05$). Besides the mentioned significant results found, no significant result controvert our hypothesis that VR editing following the 30-degree rule and 180-degree rule could bring a better viewing experience than the ones with jump cuts.

5.3 Edit Quality

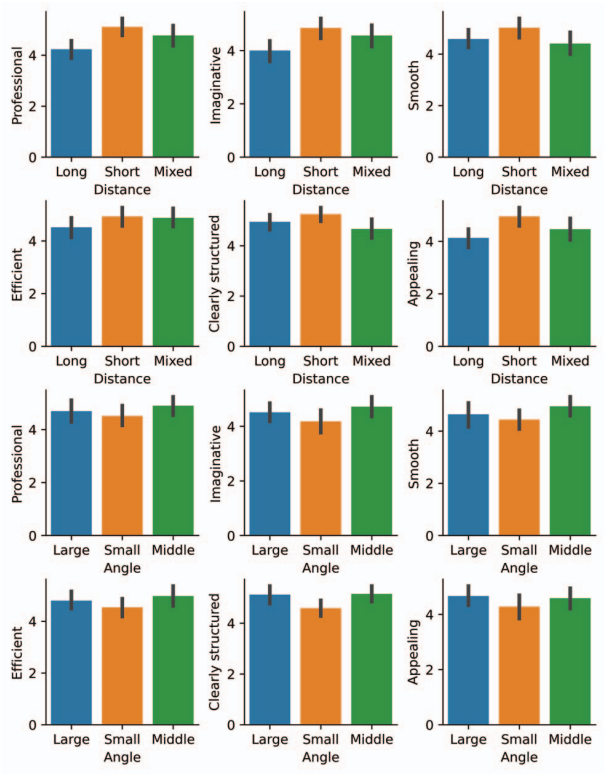

Figure 7: Effect of *Distance* (rows 1 - 2) and *Angle* (rows 3 - 4) on editing quality

The variable of distance has significantly affected to edit quality viewer perceived **Professional** ($F_{2,104} = 6.90$, $p < .01$, $\eta_p^2 = .12$), **Imaginative** ($F_{2,104} = 6.78$, $p < .01$, $\eta_p^2 = .12$), **Clearly Structured** ($F_{2,104} = 3.55$, $p < .05$, $\eta_p^2 = .06$) and **Appealing** ($F_{2,104} = 5.81$, $p < .01$, $\eta_p^2 = .10$). Camera angle has significantly affected **Clearly Structured** ($F_{2,104} = 4.14$, $p < .05$, $\eta_p^2 = .07$). Post-hoc analysis (Fig. 7) shows significant results on edits with short DRIO getting a higher score than edits with long DROI on **Professional** (Estimate = .87, t = 3.68, $p < .001$, $\eta_p^2 = .12$), **Imaginative** (estimate = .85, t = 3.62, $p < .001$, $\eta_p^2 = .11$) and **Appealing** (Estimate = .82, t = 3.39, $p < .001$, $\eta_p^2 = .10$). The result of edits with short DROI getting higher scores than edits with mixed DROI is significant on **Smooth** (Estimate = .62, t = 2.24, $p < .05$, $\eta_p^2 = .05$), **Clearly Structured** (Estimate = .59, t = 2.67, $p < .01$, $\eta_p^2 = .06$) and **Appealing** (Estimate = .49, t = 2.01, $p < .05$, $\eta_p^2 = .04$). Edits with mixed DROI get higher than edits with long DROI is significant on **Professional** (Estimate = .54, t = 2.27, $p < .05$, $\eta_p^2 = .05$) and **Imaginative** (Estimate = .56, t = 2.41, $p < .05$, $\eta_p^2 = .05$). The significant results of edits with middle camera angle having a higher score than edits with small camera angle are found on both **Imaginative** (Estimate =

.54, t = 2.30, $p < .05$, $\eta_p^2 = .05$) and **Clearly Structured** (Estimate = .56, t = 2.55, $p < .05$, $\eta_p^2 = .06$). In contrast, the same result is found on **Efficient Storytelling** with the marginally significant result (Estimate = .44, t = 1.80, p = .07, $\eta_p^2 = .03$).

Six questions evaluated the edit quality judged by users' subjective views. Overall, DROI has a significant effect on edit quality judged by the viewer, and camera angle has a more significant effect on edit quality compared to its effect on view experience. Edits with short DROI have gained higher scores than edits with long DROI or edits with mixed DROI in terms of **Professional**, **Imaginative**, **Smooth**, **Clearly Structured** and **Appealing** – 5 of 6 items relates to edit quality. No significance exists in the effect of edits with mixed DROI on edit quality. VR edit with CAD smaller than 30°, which is one of jump cut effect, gets significant negative results comparing edits without jump cuts on **Imaginative** ($p < .05$), and **Clearly Structured** ($p < .05$). The negative effect of jump cut that breaks the 30-degree rule is also found on measuring **Efficient Storytelling** with less significant data result (p = .07). Another significant result shows jump cut breaking 180-degree rule has better result in edit quality than the jump cut breaking 30-degree rule, suggesting jump cut breaking 30-degree rule could be more evident than jump cut crossing action line in an immersive environment. The VR edits following both rules successfully get relatively higher ratings on **Imaginative**, **Efficient Storytelling**, and **Clearly Structured** than the other editing methods.

6 Discussion

VR offers an unparalleled opportunity for users to immerse themselves in digital environments with a high level of freedom, blurring the boundaries between the real and the digital. As the demand for VR content continues its rapid ascent, it becomes increasingly evident that effective VR editing techniques are the cornerstone of delivering compelling and immersive experiences. This study was born out of motivation: recognising the profound impact of editing choices on the viewer's sense of presence, the overall viewing experience, and editing quality within the cinematic VR medium. This paper represents the first comprehensive exploration of the effects of jump cuts within cinematic VR. We have concluded some of the critical findings of our study.

Significance of DROI. DROI is among the most critical factors influencing the user's sense of presence, view experience, and judgement of the edit quality. Using short distance to ROI is the most effective method compared to the long distance and mix of long and short DROI. There is no evidence to show the effectiveness of editing with the interaction of VR shots with different DROI, indicating that the traditional film editing method suggests mixing shots with different DROI may not work as expected in a 360° environment. Using shorter DROI is more effective because it brings audiences closer to the story, which could explain why it significantly affects a sense of presence. Content creators and researchers have to pay attention to the DROI. Is there a specific range of DROI that could bring comfort or discomfort to viewers? Such questions need to be answered in future studies and content creation practice.

Jump Cut Effect and VR Editing Guidelines. For jump cuts' potential negative effect on viewers and the potential positive effect following the 30-degree rule and 180-degree rule, we believe the jump-cut effects exist in VR. The rules from film conventions could provide an important reference for content creators to create engaging content. We found that camera angle significantly influences the audience's judgement of edit quality more than the view experience. From the results of our study, a jump cut that crosses the 180° action line could distract the audience from the virtual world and potentially affect the sense of presence. However, the negative effect of breaking the 30-degree rule is more significant than the condition of breaking the 180-degree rule in VR, reflected primarily in the results measuring the edit quality. A significant result is shown that the jump cut breaking the 30-degree rule has a lower score than the ones breaking the 180-degree rule. A reason to explain this could be that the immersive environment has weakened the sense of "screen," and the invisible action line is not as apparent as a traditional 2D screen, which could make the jump cuts less obvious when crossing the action line. The jump cut with CAD smaller than 30 degrees gets negative results on Imaginative and Clearly Structured, which could support the idea that visual similarities exist in VR edit and could bring the feeling of less imagination and poor structure to audiences. The other important finding is that the edits we applied to traditional conventions for avoiding jump cuts have positive results on multiple items, like bringing excitement to audiences and making edits more creative. From our study, there is no direct evidence to prove that the jump-cut effects in VR share the same perception process based on traditional 2D screen mediums. Still, we successfully proved the potential negative effect caused by it in VR and the effectiveness of applying the jump-cut principles for creating potentially better VR edits. The intricate nature of VR editing design guidelines, as illustrated in Fig. 8, implies a multifaceted landscape with uncharted territories for future investigation. Building upon this study's results and design guidelines, our research scope will expand to encompass a more diverse array of shots, variables, and experimental methodologies rooted in established VR editing practices.

Advancing the knowledge of Jump Cuts in VR. Serrano et al. have demonstrated the existence of the event segmentation phenomenon in VR by replicating the cognitive studies developed by Jeffrey M. Zacks in the VR context, which has established a theoretical foundation and guidelines for applying continuity editing in our study on VR editing. Continuity editing, an important film editing method, has been applied in previous works [4, 10, 11], focusing more on viewer behaviour study, including variables such as types of edits, number, and location of ROIs. Existing works exploring VR editing methods and the application of continuity editing and event segmentation address the vital direction of studying film conventions and investigating the methodology of adapting them in VR. This process is expected to generate new knowledge of VR edits. For example, several different editing methods were identified as effective methods in Fearghail et al.'s study, which measured the distance between the intended viewing direction decided by the director and the participants' scan path of their viewing direction. [10, 11] investigated the impact of variations of VR edits on users' experience, focusing on editing crossing scenes. However, with the context of CVR content and its editing methods still underdeveloped, a limitation of existing studies could be that they were primarily based on datasets that include mainstream existing 360 videos, in which there could be limited VR edits. For instance, editing within a single scene was not included as a major study subject in the mentioned works. However, we believe it plays a significant role in VR editing and storytelling due to its tremendous application in traditional media like film.

Design Implications to VR. Our paper serves as a groundwork for providing valuable guidelines for VR content creators (Fig. 8) and insights for multimedia and VR editing researchers for further study. The guidelines aim to inspire the creators during VR editing, specifically for conditions within a single scene, which could provide guidelines for content creators to edit VR content. Furthermore, previous works did not investigate DROI as a variable in VR editing, which we found to significantly affect presence, viewing experience, and edit quality, providing novel insights for VR content creators and future researchers.

Limitation and Future Work. Our study has primarily focused on investigating the impact of varying CAD and DROI settings on user experiences in VR to discern the presence of the jump-cut effect. However, several limitations in our research merit consideration, and they lay the foundation for future avenues of exploration:

- Limited participant pool. In the user experiment, the relatively

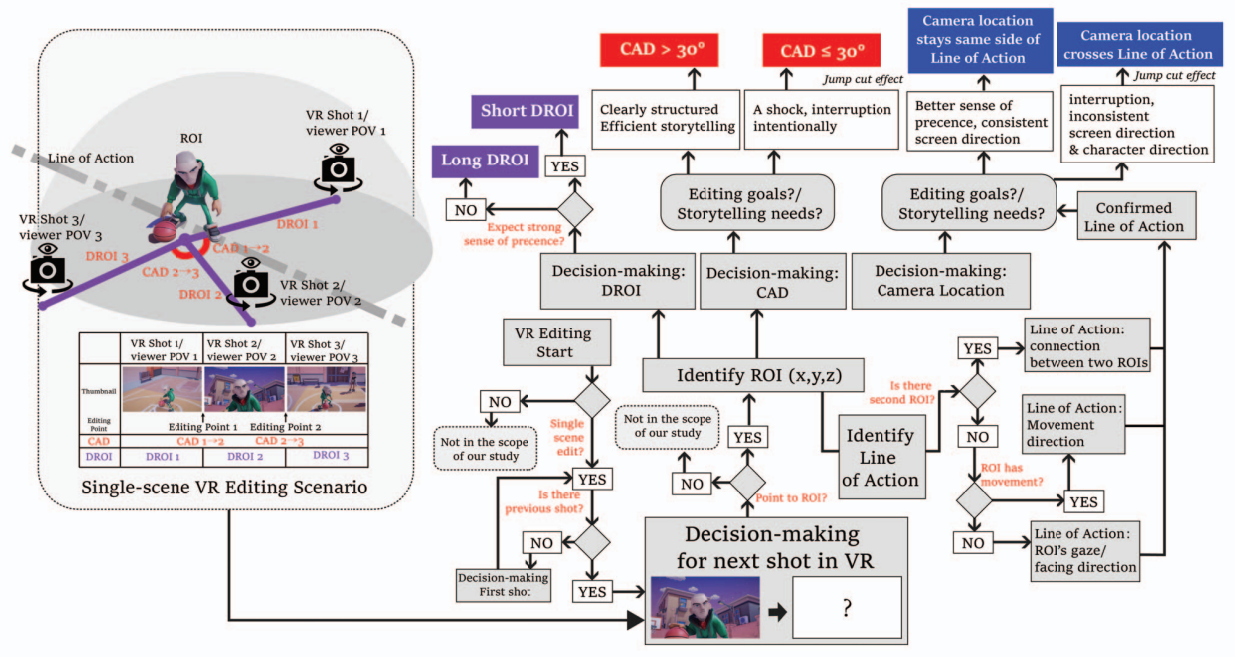

Figure 8: Design guidelines for VR Editing, with the decisions on DROI (purple), CAD (red), and Camera Locations (blue).

low number of participants and the predominant representation of university students may restrain the generalizability of our findings. Drawing insights from comparable studies [18, 19], our future research endeavors will incorporate results and data from an expanded user study. This forthcoming study aims to include a more diverse participant pool, encompassing individuals of varied ages, backgrounds, and races, to provide a more comprehensive understanding of the study.

- Limited diversity in genre and storytelling aspects. The diversity of VR storytelling genres within our experimental materials was restricted, posing a threat to the generalizability of our findings. Different VR story genres may employ distinct CAD and DROI settings, each with unique effects on audience perception. Future research should encompass a broader range of VR storytelling genres, considering their specific narrative needs and examining the utilization or mitigation of the jump-cut effect within these contexts.

- Oversimplified scene. In our study, we opted for a simple scene design (one scene with two ROIs) to facilitate the investigation of VR edits. This decision allowed for clear ROIs and a straightforward line of action, aligning with our primary objective of examining the 30-degree rule and 180-degree rule in VR. However, we acknowledge that visual storytelling often involves intricate scene designs with multiple ROIs and complex lines of action within a single scene. For future research, we intend to incorporate scenes with more elaborate designs, exploring variations in the number of ROIs, lines of action, the complexity of surroundings, and edits involving multiple scenes.

- Omission of temporal factors and VR sickness. Another notable limitation pertains to our omission of temporal factors. Existing literature underscores the pivotal role of time in shaping viewer perception and behavior within the VR realm. We acknowledge that VR sickness, a parameter not evaluated in this study, could yield valuable insights for formulating design guidelines and factors such as immersion time and camera settings.

- Overlooked gender as a study subject. Existing research has provided evidence that participants' gender could influence VR perception. Due to the limited study pool, the gender difference in viewing experience was not thoroughly investigated, which could be one crucial factor to examine in future VR editing studies [28, 29].

7 Conclusion

Compared to traditional 2D-screen mediums, where filmmakers have complete control over framing, VR editing presents unique challenges and is quoted as one of the most significant hurdles in VR storytelling [3]. Filmmakers in the context of CVR no longer have the same level of control over framing. Multimedia researchers are investigating how VR editing can support creators in creating high-quality and creative VR content. One approach is the adaptation of traditional filmmaking conventions. With the establishment of applying continuity and event segmentation theory in VR [4, 10, 11], our paper aims to identify the potential negative and positive effects in VR editing based on traditional film conventions, focusing on the 30-degree rule and 180-degree rule, with consideration of DROI. While mainstream VR editing practices and existing relevant research have focused on designing methodologies of VR editing that focus on transition-crossing scenes, we have focused on VR editing within a single scene to fill this gap.

We highlight that DROI is an essential factor influencing the viewer's sense of presence, viewing experience, and judgement of the edit quality. Specifically, a shorter DROI seems to create positive effects in these areas and should be used more in editing for an engaging experience. Moreover, the film convention of the 30-degree rule should be considered during VR editing based on its potential to produce positive or negative edits on edit quality and viewing experience, which could indicate that visual similarities should be avoided in editing for an engaged experience. Identifying the action line and

noticing the 180-degree rule is also needed during VR editing due to its potential effect on the sense of presence. While our work underscores the significance of DROI in shaping viewer experiences and editing quality – highlighting, for instance, the favourable impact of shorter DROI over longer DROI – a deeper comprehension of the comfort range and overall effectiveness demands further dedicated exploration. As our endeavors progress, we anticipate contributing to the nuanced understanding of VR editing's intricacies and the broader landscape of viewer engagement. Finally, we answer the research questions raised at the beginning:

Q1. Jump cuts exist in the VR context, especially those that break the 30-degree rule with high visual similarities. Visual similarities in VR are the main reason for the jump cut effects ($CAD < 30$), as it was addressed as the main reason in traditional 2D-screen medium [6,7]. However, it is outside our scope of study and requires further study.

Q2. Regarding how an audience perceives a jump cut in CVR, we do not have sufficient evidence for reasoning the relationships of multiple factors. More importantly, the jump effect causes a lower sense of presence, a feeling of poor structure, and low efficiency in storytelling.

Q3. By applying the 30-degree rule and 180-degree rule, the VR jump cuts we generated could negatively affect the audience's viewing experience. Specifically, jump cuts breaking the 30-degree rule have a more significant effect on potentially poor viewing experience and lead to the audience's negative judgement on edit quality. The jump cut breaking the 180-degree rule could distract audiences from engaging experiences from the virtual experience.

Q4. VR edits that follow the 30-degree and 180-degree rules and avoid jump cuts can provide a more engaging viewing experience than those that include jump cuts.

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