第 28 回日本バーチャルリアリティ学会大会論文集（2023 年 9 月）

Vection Role in Virtual Reality: From the Presence and Motion Sickness Perspectives

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Abstract：Vection is a commonly experienced visually induced illusion of self-motion, often observed and can be seen as the experience of movement in the virtual reality world. It is typically perceived to occur in the opposite direction to the visual stimulus motion. With the rising popularity of virtual reality and the genuine sensation of self-movement it provides, the role of vection has gained significant attention. This paper aims to explore the role of vection in virtual reality, focusing on its impact on presence and motion sickness over the last decade. The findings reveal a positive correlation between vection and presence. Furthermore, vection tends to precede the onset of motion sickness. However, the relationship between the vection and motion sickness may be related to the vection strength, stimuli type, and individual differences. Additionally, vection has been found to alleviate motion sickness. For future research, it is recommended to simultaneously measure vection, presence, and motion sickness in the same experiment. Moreover, incorporating a broader range of visual stimuli and integrating multisensory modalities in real stimuli could enhance the vection experience and sense of presence. This would help to further elucidate the role of vection in virtual reality. Furthermore, the role of vection in self-spatial orientation during virtual driving and in virtual psychotherapy should also be considered for further investigation.

Keywords：Vection, Presence, Motion sickness, Virtual Reality

1. Vection

Vection is a prevalent phenomenon in everyday life, with a classic example being the train illusion, where perceiving the movement of adjacent trains can create the illusion that the stationary train you are on is also moving. Researchers investigating the neural mechanisms involved in perceiving and controlling self-motion have frequently studied vection [1-3]. When a large area of their visual field is filled with coherent motion, stationary observers often perceive the illusion that their body is moving in the opposite direction to the visual motion, as depicted in Figure 1. Vection is almost always perceived to occur in the opposite direction of the visual stimulus motion. The measurement of vection intensity typically relies on subjective self-report measures, encompassing three key indicators: latency times, duration, and subjective ratings of vection strength. The experience of vection can be influenced by manipulating various physical properties of the visual inducing stimulus, such as luminance contrast [4] and its optical/retinal size [1], among others. Research has also demonstrated that higher-level cognitive factors (e.g., attention, stimuli naturalness, etc.) influence observer experiences of vection [5].

Vection is typically a subjective illusory experience triggered by visual grating motion stimuli presented in a 2D display environment. Previous research has demonstrated that vection experiences can also be induced by auditory and tactile stimuli [6-7]. If the stimulus can be presented in different modalities and rendered more realistically and immersed for an extended period, such as through virtual reality (VR) [8], would there be no difference between the vection illusion experience and our real movement? In this case, it may feel the same as actual self-movement, leading to the loss of the illusion of moving while actually moving. Thus, at this point, vection may not be the typical self-motion illusion experience we understand; instead, it can be perceived as actual movement in the metaverse space vection. This interplay might be the reason why vection, presence, and motion sickness are closely related. With the increasing popularity of virtual reality and its ability to provide a sense of genuine self-moving experiences, the role of vection in virtual reality has garnered significant attention. However, it remains unclear how different stimuli affect vection, presence, and motion sickness, and how these factors interact with each other. Therefore, this paper aims to summarize the relationship between presence, motion sickness, and vection in virtual reality over the last decade, while also proposing potential directions for future research.

2. Vection and Presence

The virtual world is an illusionary and virtual creation that combines information from various sensory modalities. The term "metaverse" refers to a virtual space serving as a network connecting multiple virtual spaces with each other [9]. An essential characteristic of the metaverse is its ability to provide users with an enhanced sense of presence. Presence refers to the feeling of complete immersion in the virtual world and a profound connection with the virtual environment, making it highly similar to the real world [10].

Over the past decade, research on the relationship between vection and presence has yielded valuable insights into the perceptual and experiential aspects of immersive environments. Studies have found a positive correlation between the intensity of vection and the sense of presence. For instance, when forward self-motion in depth was simulated in virtual reality using Oculus Rift head-mounted display, participants who performed different sequential yaw head movements consistently showed trends in both vection and sense of presence. Therefore, this positive relationship holds even with a wide range of head-to-display lags [11]. Similar results were observed in spatial presence when participants observed different optical flow stimuli using a head-mounted display virtual environment. It was found that anisometropia suppression reduced both vection intensity and spatial presence [12]. Moreover, this positive relationship remains unaffected by visual-induced motion sickness, known as cybersickness [13]. These findings suggest that the strength of vection can enhance the sense of presence, leading to a more immersive and engaging experience in virtual environments. Additionally, studies have examined the role of cognitive factors and multisensory integration in shaping the relationship between vection and presence. For example, walking naturally in a virtual environment is often challenging. To address this, researchers developed the foot tactile system and found that simultaneously presenting visual, auditory, and oscillatory tactile cues enhanced vection intensity and improved the sense of presence [14]. This indicates that how stimuli are presented may influence the relationship and tendency of vection and presence. In conclusion, understanding the relationship between vection and presence is crucial for designing immersive virtual environments that provide users with a more realistic and compelling experience.

3. Vection and Motion Sickness

When strong or conflicting visuomotor stimuli are introduced, such as rapid rotation, or a mismatch is created between visual and vestibular stimuli cues, such as, presenting conflicting visual and vestibular cues about the direction or magnitude of self-motion. At this time, it is easy to have motion sickness, which is another common side phenomenon of virtual reality. Previous studies have assessed motion sickness using questionnaires, including a recent study that employed six short visually induced motion sickness susceptibility questionnaires. The findings revealed a strong correlation between motion sickness and susceptibility to motion sickness caused by car rides, migraines, and urban vertigo [15]. The relationship between vection and motion sickness is complex, as demonstrated by prior research. Some studies have shown that vection experiences can occur without accompanying motion sickness, while others indicate that both can co-occur simultaneously [16]. However, recent experiments suggest that vection may not be the direct cause of motion sickness [17]. The connection between vection and motion sickness seems to be influenced by factors such as vection strength, stimuli type, and individual differences. Subsequent experimental studies have demonstrated that altering stimulus characteristics, such as density, speed, and increased rotation, can modify the intensity of vection, but this change in vection does not always correlate with a corresponding increase in motion sickness intensity [18]. Although motion sickness intensity may generally increase with vection intensity, the relationship varies among participants [19].

Hence, vection may lead to motion sickness experiences in virtual reality (VR) and other visually immersive environments. Some studies have found a positive correlation between the intensity of vection and the severity of motion sickness symptoms. However, other studies have reported weaker or no significant relationship between vection and motion sickness. Therefore, while vection generally precedes motion sickness, the nature of the relationship between the two varies depending on different experimental stimuli and study conditions. Previous research has also explored strategies to mitigate vection-induced motion sickness, such as slowing down stimulation speeds and providing adaptive vection experiences based on individual sensitivities. Such as, a recent study showed that stronger vection was associated with higher motion sickness levels, particularly when rotational motion occurred at increased rotational speeds and low linear velocities and also found that motion sickness could be mitigated by reducing rotational speed [20].

4. Future Directions

This study focuses on the role of vection in virtual reality, systematically combs its relationship with vection from the perspectives of sense of presence and motion sickness, and explained it from the perspective of stimulus presentation and vection as the movement in the virtual world. Among them, there is a positive correlation between vection and presence, and vection appears before motion sickness, and their relationship is more complicated. However, there are still some unresolved problems in this field, and future research can be expanded from these directions.

4.1 Simultaneous Measurement

Previous studies have explored the relationship between presence and motion sickness, revealing a negative correlation between these two factors [21]. Since the symptoms and physiological changes of cybersickness (experienced in virtual reality) and motion sickness (triggered by motion stimuli) are essentially the same [22], this negative relationship was also observed in the context of cybersickness and presence [23]. These findings demonstrate the existence of a complex relationship among vection, presence, and motion sickness, which requires further research to clarify their interplay (refer to Figure 1). In a recent study, researchers found that a significant increase in vection intensity for the water condition. However, there were no notable differences in visually induced motion sickness or presence between standing on the ground and floating in water conditions during the VR experience [24]. This suggests that simultaneous measurement of these three indicators (vection, presence, and motion sickness) in the same experiment would be beneficial in unraveling the role of vection in virtual reality. While the relationship between vection, presence, and motion sickness has been explored in previous studies, there has been limited simultaneous measurement of these three factors in the same experiment. Therefore, future studies could incorporate simultaneous measurement, using similar subjective reporting tools. This approach would enable accurate comparisons between the three indicators and provide further experimental evidence for predicting changes in one indicator based on the values of the other two in the future.

4.2 More Real Stimuli

With new research findings that other sensory modalities can also successfully induce vection experience and the development of virtual technology, then vection may not be virtual at this time, especially if the stimulus is more realistic and immerse more time. Using 3D virtual reality technology to present stimuli will be a more realistic method. For example, previous studies have used head-mounted displays (HMD) and head-tracking systems to create a multisensory environment that more realistically immerses participants in this virtual world. In the virtual world, the addition of stimuli that can pass through more sensory modalities will make the entire virtual stimuli more realistic, because this is very similar to our multi-sensory world in the real world. Thus, this is a very useful way to increase vection and sense of presence [17]. In addition, there is a more realistic method, that is, we can use stimuli that are highly relevant to reality or generate similar stimuli. For example, previous studies have found that the more natural the stimulus, the stronger the intensity of vection. Finally, we can also develop new virtual presenting techniques to increase the realism of stimuli and thus improve presence. For example, researchers have developed new AR presentation technologies and found that the teaching effect was better than the traditional teaching method, especially in the sense of presence [25].

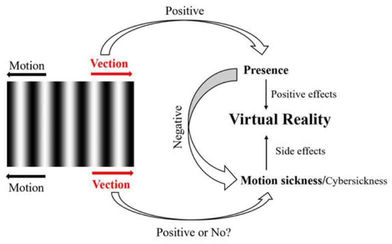

Figure 1: Vection direction (black arrow) and the inducing visual stimulus motion (red arrow) are almost always opposite. Vection is positively correlated with presence, and there is also a positive correlation with motion sickness, but some results did not find this relationship, and motion sickness can be reduced through vection. In the future, the relationship between vection, presence and motion sickness need to be further clarified.

4.3 Clinical and Practice Scenes

This more realistic stimulation makes participants feel more real, which has a certain real and effective effect in psychotherapy. For example, exposure therapy is difficult to implement due to the limitations of the real environment. Currently, the virtual world is a valuable choice for exposure therapy, and it turns out that VR exposure is a better treatment [26]. If the patient can be better immersed in this environment, such as feeling the movement and enhancing the sense of immersion, it will help the patient to extend the feeling in the experience to the real world. For example, their motion experience is compensated, and they no longer fear certain specific fears. In addition, it is also used in virtual driving. Previous research has found that by using the vection with an augmented reality system can reduce the effect of the real acceleration in the vehicle which is mainly the factor for motion sickness [27].

Acknowledgements This work was supported by JST SPRING, Grant Number JPMJSP2136.

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