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RESEARCH NOTE

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Physiological measurement techniques in virtual tourism research: three caveats for future studies

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ABSTRACT

Research on virtual tourism is receiving substantial scholarly attention. Existing studies on virtual tourism tend to apply self-report methods to assess user experiences, overlooking the potential of physiological measurement techniques. Empirical work in conceptually related areas, contends physiological methods have a demonstrated capacity to unearth unconscious mental processes, which can help mitigate potential cognitive biases and yield objective data. This short commentary draws on an exemplar of research conducted with 20 participants in a virtual nature-based tourism environment to critically assess the efficacy of emergent physiological techniques for assessing user engagement in virtual tourism environments. Outcomes demonstrate that eye-tracking was an effective technique for analysing attention in virtual tourism environments, revealing participants paid more attention to human activities in nature than pure natural elements. While Galvanic Skin Response was less effective in assessing emotional responses, the technique still offers potential for future scholars. This research contributes three key caveats and a three-step roadmap to apply the caveats for future studies to consider when applying physiological methods in virtual tourism research.

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Virtual reality; virtual tourism; physiological methods; eye-tracking; galvanic skin response

Introduction

Tourism experiences in virtual reality (VR) are gaining mounting academic interest, with scholars noting the potential of immersive technology to showcase destinations in the virtual world and influence consumer behaviours, as well as enhance an existing experience or serve as an alternative mode of travel (Geng et al., 2024; Huang et al., 2020). VR tourism is characterised by the ability to visualise tourism scenes in the virtual world, offering users a sense of immersion and psychological presence (Yung & Khoo-Lattimore, 2019). This ability requires advancing knowledge on the aspects of virtual tourism environments that capture the attention of users (Adhanom et al., 2023). Subsequently, emotion has been conceptualised as a pivotal factor in emerging research on virtual tourism experiences (Moyle et al., 2019). Emotions are important in virtual tourism research due to the application of physiological measurement techniques and their subsequent relevance to advance the conceptual understanding of user engagement and satisfaction (Geraets et al., 2021; Somarathna et al., 2023; Yung et al., 2021).

Despite exponential growth, existing studies on virtual tourism have predominantly relied on self-reported methods to explore user experiences within virtual environments (Bec et al., 2021). Such reliance introduces several critical issues that hinder the conceptual advancement of VR tourism research (Hadinejad et al., 2024). Relying predominantly on self-report methods to conduct research on user experiences with VR tourism neglects the potential to capture real-time responses, which are beyond participants' consciousness (Li et al., 2018). In addition, asking participants to recall VR tourism experiences post hoc is subject to cognitive bias and socially desirable responses (Wang & Sparks, 2016). Such limitations associated with self-report methods justify an emerging trend towards the infusion of objective methods in VR tourism research, with physiological measures presenting a viable alternative to advance discourse on the methods, which can be applied to provide new theoretical insights (Liu et al., 2024).

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Physiological measures have a strong potential to advance VR tourism research through real-time objective measurement of cognitive and emotional responses, mitigating potential biases prevalent in self-report methods (Slevitch et al., 2022). VR tourism is a visually dominant activity, so having an objective understanding of tourists visual attention is important to identify their visual patterns and engagement (Scott et al., 2019; Xie et al., 2023). Eye tracking is a physiological method that objectively assesses eye movement and attentional processes (Walters et al., 2023). Eye-tracking allows for a real-time and accurate identification of specific areas of stimuli that participants are looking at by tracking and mapping their eye movement (Wang & Sparks, 2016). Attentional processes may occur beyond human awareness, and too rapidly to be captured using self-report methods, with eye-tracking offering an opportunity to address this limitation (Scott et al., 2019). By analysing pupilary dilation, Slevitch et al. (2022) suggested that eye-tracking has the potential not only to examine attention but unearth discrete emotions.

Galvanic Skin Response (GSR) is articulated in empirical work to have a strong potential to provide a nuanced understanding of emotional responses in VR tourism (Bastiaansen et al., 2022). GSR, which is also known as skin conductance or electrodermal activity, is a measure of emotional responses (Lei et al., 2022). The GSR technique measures skin electrical conductivity as a reaction to sweat secretion to understand emotional responses (Li et al., 2023). Proponents note a key advantage of GSR for assessing users' experience in virtual environments is its ability to provide real-time insights into unconscious emotional reactions (Brodien Hapairai et al., 2018).

Despite recent advancements in biometric measurements, there are limited studies that apply physiological measures in VR tourism research. Instead, studies that apply physiological methods tend to focus on static traditional tourism marketing advertisements (Yung & Khoo-Lattimore, 2019). Limited exceptions have applied physiological methods such as skin conductance (Bastiaansen et al., 2022), heart rate (Huang et al., 2020; Liu & Huang, 2023) and eye-tracking (Slevitch et al., 2022). These studies have demonstrated the capability of physiological methods in capturing users' experience with VR, extending the virtual tourism methodological knowledge beyond self-report methods. However, the lack of guidelines and best practices in the implementation of physiological methods for VR in tourism remains a distinct gap that needs to be addressed.

Consequently, this paper is designed to stimulate constructive discourse on the application of physiological techniques in VR tourism research. Accordingly, this research, based on a case study of a natural-based destination in Australia, aims to critically assess issues associated with the application of physiological measurement techniques in virtual tourism research.

Method

This research is part of a broader project, which focuses on how high and low human activities influence tourists' physiological responses. Stimuli with high human activities contain a large number of people, while low human activity means a small number of people. To ensure an effective manipulation, a rigorous process pioneered by Liu et al. (2024), which included (1) context selection; (2) field filming and (3) expert evaluation and preliminary testing, was adopted. To reduce potential compounding effects, two separate stimuli were filmed at one destination at different times. The stimulus with high human activity was filmed during the middle of a public holiday when there were plenty of people visiting the place, while the one with low human activities was filmed on a normal weekday early morning to ensure the minimal appearance of people. This approach is based on the challenges encountered in finding existing stimuli that could adequately meet the specific needs of the research, particularly in terms of ensuring ecological validity and alignment with the intended research objectives.

This research note critically reflects on the application of eye-tracking and GSR to measure attention and emotional responses in a VR tourism environment with high human activities, focusing on tourist wellbeing. The VR tourism stimulus was a 360-degree VR video that closely replicates real-world experiences of a nature-based tourism destination on the Gold Coast, Australia, featuring vibrant visual aspects such as a natural rock pool, green trees, and individuals participating in diverse nature-based activities. The stimulus was approximately 5 min long.

This research utilised an HTC VIVE Pro Eye VR headset with eye-tracking capabilities, which allow for participant freedom of movement and comfort, while effectively capturing and recording eye movements. Based on the recommendation of Li et al. (2018), GSR was selected to measure tourists' emotional arousal to the VR stimuli. The GSR device comprised two electrodes attached to participant's fingers, connected to a transmitter. Data were processed in the iMotions platform, explicitly designed to collect and process several types of physiological data (Slevitch et al., 2022).

Twenty participants mainly comprised of students and PhD candidates from an Australian university successfully completed the VR tourism experience in a laboratory-based setting. Recruiting students as research participants is justified because they often exhibit similar response patterns compared to non-students (Slevitch et al., 2022) and are usually early adopters of new technologies (Wei et al., 2023). Based on recommendations from Yung et al. (2021), participants were purposefully recruited, and comprised of individuals aged between 18 and 35, who possessed normal hearing and vision, without prior record of motion sickness, seizure or epilepsy. Recruitment was conducted using purposeful and snowball sampling to ensure participants met the specified criteria. No monetary incentive was provided in order to minimise potential biases that might arise from financial motivations. By relying on purposeful and snowball sampling, the study aimed to recruit participants who were genuinely interested in the research topic, ensuring that their engagement and responses reflected their natural reactions to the virtual tourism experience rather than being influenced by external rewards. This approach helped to maintain the integrity and authenticity of the data collected. This sample size of 20 was appropriate for studies employing physiological methods (Scott et al., 2019).

Participants were informed about the research and asked to sign a consent form. After participants put on the VR headset, the GSR electrodes were placed on their index and ring fingers to record their electrodermal activity (van Dooren et al., 2012). Participants were asked to take deep breaths to test the GSR data quality, and a five-point calibration process was used to ensure the quality of eye-tracking data (Wang & Sparks, 2016). Participants were instructed to watch the VR stimuli without specific requirements to facilitate a truly immersive experience (Wei et al., 2023). When participants were watching the VR stimulus, the equipment collected their physiological responses simultaneously and sent data to the iMotions software for subsequent analysis. After the VR experience, participants completed a short interview, which focussed on their visual attention and emotional responses to the experience. This paper adopted semi-structured interviews, using example questions including: 'Describe what you saw in the VR experience. Of those things, which one did you spend the most time looking at? Describe some of the thoughts and feelings you had during the VR experience.'

Following a procedure implemented by Li et al. (2022), gaze mapping and dynamic Area of Interest (AOI) techniques were applied to analyse and visualise eye-tracking data. Initially, individual gaze maps were created and processed, which were then aggregated to create heat maps. Dynamic AOIs were created to track visual attention on moving objects. GSR data were exported and analysed by calculating skin conductance reading frequency (i.e. number of peaks) and amplitude (i.e. size of peaks) (Hadinejad et al., 2019).

Results

Figure 1 presents an exemplar of the heat map results and a reference image without heatmap, which depicts a scene of people on a cliff at the natural rock pool. Results reveal visual attention of tourists with the redder zones in heat maps indicating longer fixation duration. An observable pattern is participants directed more attention to human activities than to natural scenery. Our findings are perhaps slightly different from real-life nature-based tourism settings, where previous studies found that people tend to focus on natural scenery when they travel to real-life nature-based tourism destinations (Hanna et al., 2019; Qiu et al., 2021). In virtual tourism settings, the dynamic and immersive 360-degree VR scenes closely replicate real-world experiences. However, in contrast to prior work, attention moves away from dynamic natural elements and towards dynamic human activities in a virtual natural landscape, which contrasts with patterns observed in actual nature-based tourism settings. Future studies should explicitly consider the dynamics of social presence in virtual nature-based tourism settings and subsequent implications for tourism marketing and destination management. The unexpected finding also opens avenues for future research to

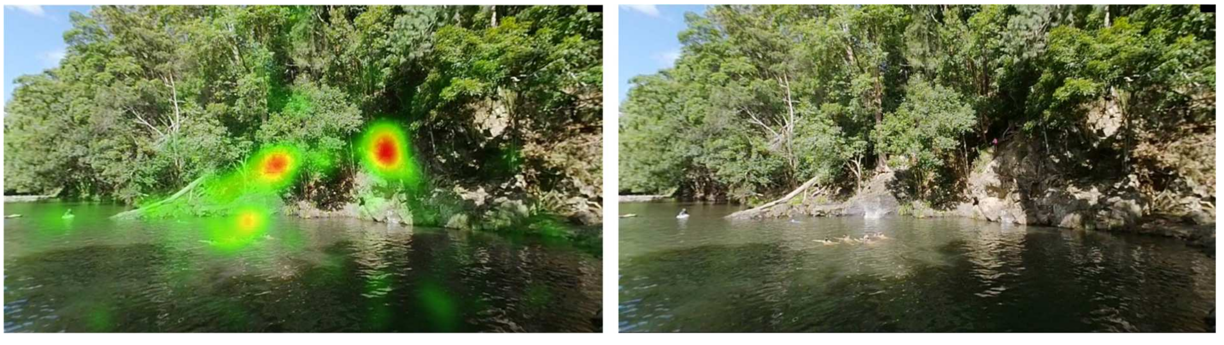

Figure 1. Heat map and reference image example.

further explore attention patterns in virtual tourism environments. Interview responses revealed a similar pattern, as participants commented that they directed their attention towards people swimming in the rock pool or jumping down from the rock, and these scenes created a senses of enjoyment and excitement. In VR tourism, it is impossible to create an aggregate heat map or similar medium to illustrate participants' visual attention across the entire stimulus, and consequently, researchers must select which parts of the stimuli to investigate based on concepts of interest. Interviews were aligned with the physiological data, with participants speaking extensively about the dog swimming with its owner. Accordingly, a dynamic AOI was used to measure participants' attention towards a moving object, which in this instance was a dog swimming in the rock pool (Table 1).

The results showed that nine participants fixated on this dynamic AOI (i.e. the swimming dog). On average, the swimming dog attracted 60.8 fixations and a considerable dwell time of 10,082.98 milliseconds, indicating a significant portion of attention was directed on the moving object. The results indicated that the dynamic AOI created in this research was particularly useful in capturing visual attention towards dynamic objects, which opens opportunities to use eye-tracking in more interactive VR stimuli. However, using dynamic AOIs requires researchers to manually create them for each moving object they are interested in, and this involves significant time and effort.

GSR was not particularly effective in measuring tourists emotional reactions when exposed to VR tourism experiences. This happened as participants initiated various hand movements when they watched the VR tourism experience, which subsequently led to interference in the GSR data. It was possible for participants to keep their hands in a relaxed position when testing the GSR signals, but during the actual VR tourism experience, it became impossible to regulate hand movement, with participants' freely moving their hands when viewing the stimuli, leading to electrical interference. Although the GSR technique was able to identify peaks in the electrodermal activities of some participants, data did not come from other participants, resulting in the graph depicting that their emotional reaction was almost a straight line. These data were excluded from the data set. This zero-response result might be because of physiological variability (Guerrero-Rodríguez et al., 2020), however such outcomes suggest that GSR requires careful implementation when applying to virtual tourism research. The following section presents three caveats for future researchers to consider when applying physiological measurement techniques in virtual tourism research.

Table 1. Dynamic AOI metrics.

Metrics	Numbers
Respondent count (gaze dwells)	9
Fixation count	60.8
Dwell time (fixation, ms)	10082.98

Three caveats for future research

Caveat 1: enhancing the validity of virtual tourism research

To improve internal validity, future VR tourism studies are recommended to meticulously consider the validity and reliability of VR stimuli. Existing studies have largely depended on externally produced VR stimuli, which can introduce the risk of including irrelevant stimuli that could confound study results (Liu & Huang, 2023). For this reason, using such VR content may lead to inaccuracies in representation, limitations in customisation, reduced interactivity and immersion, and difficulties in comparing results due to variations in the selected stimuli (Chen et al., 2022). Liu and Huang (2023) concur, acknowledging that most studies emphasise the importance of stimuli selection over the production of tailored stimuli that best suit research objectives. Emergent research demonstrates the efficacy of adopting rigorous procedures to develop VR stimuli, with an emphasis on the manipulation and control of confounding factors and multi-measurement techniques for assessment (Liu et al., 2024). This research calls for future studies to advance emergent discourse on the development of tailored virtual experiences, with a focus on the design, development and production of VR stimuli for application in tourism research.

Future studies should continue to examine the concept of presence and its various dimensions, including physical and social presence, within the context of virtual tourism. Researchers are encouraged to manipulate these dimensions when designing VR stimuli to assess their effects on user engagement. By systematically varying levels of presence, researchers can gain deeper insights into how different aspects of presence influence user experiences. Additionally, employing biosensors to measure physiological responses can provide valuable data on how varying levels of presence impact user engagement in virtual tourism settings. This approach not only enhances the understanding of presence but also allows for a more nuanced exploration of the relationship between presence, emotional responses, and overall user satisfaction. By investigating these interactions underpinned by physiological measures, future research can contribute to a more comprehensive framework that informs the design and implementation of immersive virtual tourism experiences.

This research demonstrated the effectiveness of the dynamic AOI technique in analysing visual attention towards dynamic objects. As virtual reality is immersive and dynamic in nature, static AOI might not be able to fully reveal attention towards movements within the virtual environment. A novelty of this research is the quantification of dynamic AOI, which has rarely been applied in existing studies. While it seems natural that humans would pay attention to dynamic objects, few studies have attempted to measure this using dynamic AOI techniques. This research therefore offers a novel approach for future studies to attain a deeper understanding of visual patterns and how users interact with dynamic elements in different virtual tourism contexts (Savin et al., 2022).

Compared to conventional types of stimuli (e.g. images or videos), VR stimuli have the potential to closely resemble real-world settings, enhancing the external validity of VR tourism research. The effectiveness of dynamic AOI demonstrated in this research also opens avenues for future studies to examine non, semi, and fully immersive VR systems in tourism (Beck et al., 2019). For instance, fully immersive and interactive VR experiences allow users to freely move within the environment, which more closely reflects actions and navigations in real tourism. Therefore, using fully immersive and interactive VR will enhance both external and ecological validity compared to 360-degree VR (Yung et al., 2021). Future research could incorporate eye-tracking to compare the mental imagery process and sense of the presence of different VR formats, such as 360-degree VR and 9D or interactive VR (Liu & Huang, 2023).

Caveat 2: optimising techniques and equipment in virtual tourism research

This research suggests that scholars should carefully consider their techniques and equipment when using physiological methods in future VR tourism studies. Future scholarship on VR tourism could adopt a multimodal approach using different biosensors to simultaneously measure various human senses, for example, eye-tracking for visual attention, and other techniques like GSR for emotional arousal. When doing so, it is important to consider if the platforms being used could synchronise multiple biosensors. The iMotions platform used in this research can do this automatically, yet other platforms may not have this capability. Researchers using platforms without automatic biosensor synchronisation may consider manual synchronising techniques by aligning the timestamps of different biosensor recordings where possible to compare across different biosensor results.

Future research should also take steps to minimise electrical interference when combining GSR with eye-tracking in VR headsets to enhance the internal validity of data. Skin conductance studies typically place electrodes on the non-dominant hand to minimise movement interference (Brodien Hapairai et al., 2018; Li et al., 2018). VR tourism studies tend to follow this practice without providing explicit justification (e.g. Slevitch et al., 2022). However, in VR tourism research, this can be problematic due to electrical interference from VR headsets and cables. This issue is more salient in VR tourism research due to the complex nature of equipment setups which involve several cables to connect the headset to a computer (Guillen-Sanz et al., 2024), while traditional media such as images or videos typically involve simpler setup such as a computer screen only. Non-tourism VR studies also recognise that biosensors such as GSR or EEG are prone to electrical interference from the VR equipment and cables (Hanshans et al., 2024; Petrescu et al., 2020). This complex setup can increase the likelihood of electrical interference when GSR is used. To address the issue of hand movement during VR experiences, GSR electrodes should be placed on the hand that is further away from VR cables to reduce interference. Participants should receive clear, detailed pre-task instructions on minimising unnecessary hand movements while ensuring their immersion in the virtual experience remains intact. Additionally, participants should be closely monitored during the VR sessions to further reduce hand movement. To enhance the reliability of the data collected, future research could introduce a brief warm-up session prior to the main experiment. This session would present pre-experiment VR stimuli, helping participants relax and become familiar with the equipment, thus minimising excessive hand movements and improving the accuracy of physiological measurements.

Future studies should also consider GSR placement strategies to minimise the potential for electrical interference. This research acknowledged that placing GSR on fingers might create electrical interference due to hand movements. van Dooren et al. (2012) found that fingers, feet, and shoulders are the most electrodermal-responsive areas of the body. To reduce interference from hand movements in virtual tourism studies, future research could consider placing GSR electrodes on less movement-prone areas, such as the feet or shoulders, as an alternative to the fingers. However, this adjustment may require the use of specialised GSR devices designed for these alternative placements to ensure accurate data collection.

Caveat 3: towards data triangulation in virtual tourism research

Future studies should use complementary data sources such as self-report methods, document analysis, or observation to triangulate with biosensor results. The intersection of VR and tourism raises complex research questions that single-method studies might not fully address, even with multi-phased experimental designs. Relying solely on physiological data may provide an incomplete picture of user perceptions and experience with virtual tourism (Lei et al., 2022). Triangulation facilitates a multi-faceted approach, not only enabling researchers to tackle complex questions from different angles and produce more robust answers but also capturing the nuances of both objective and subjective approaches to understand the virtual experience (Li et al., 2023). Furthermore, future studies may explore the use of motion sensors to triangulate GSR data. Incorporating a motion sensor could enable a deeper understanding of how participants' movements may influence their psychological responses. This could provide valuable insights into the GSR results, offering a more nuanced understanding of physiological responses.

Road map for application

A three-step road map for applying the three caveats in future virtual tourism studies which seek to apply physiological measures is displayed in Figure 2. The road map highlights how the three caveats can be applied at different stages of the research process to improve research quality. In Step One, when preparing for a study in virtual tourism, researchers should consider the reliability and validity of their stimuli, and produce customised stimuli that align with specific research objectives. Scholars should consider immersive and interactive VR stimuli as these stimuli more closely reflect the interactions in real tourism settings.

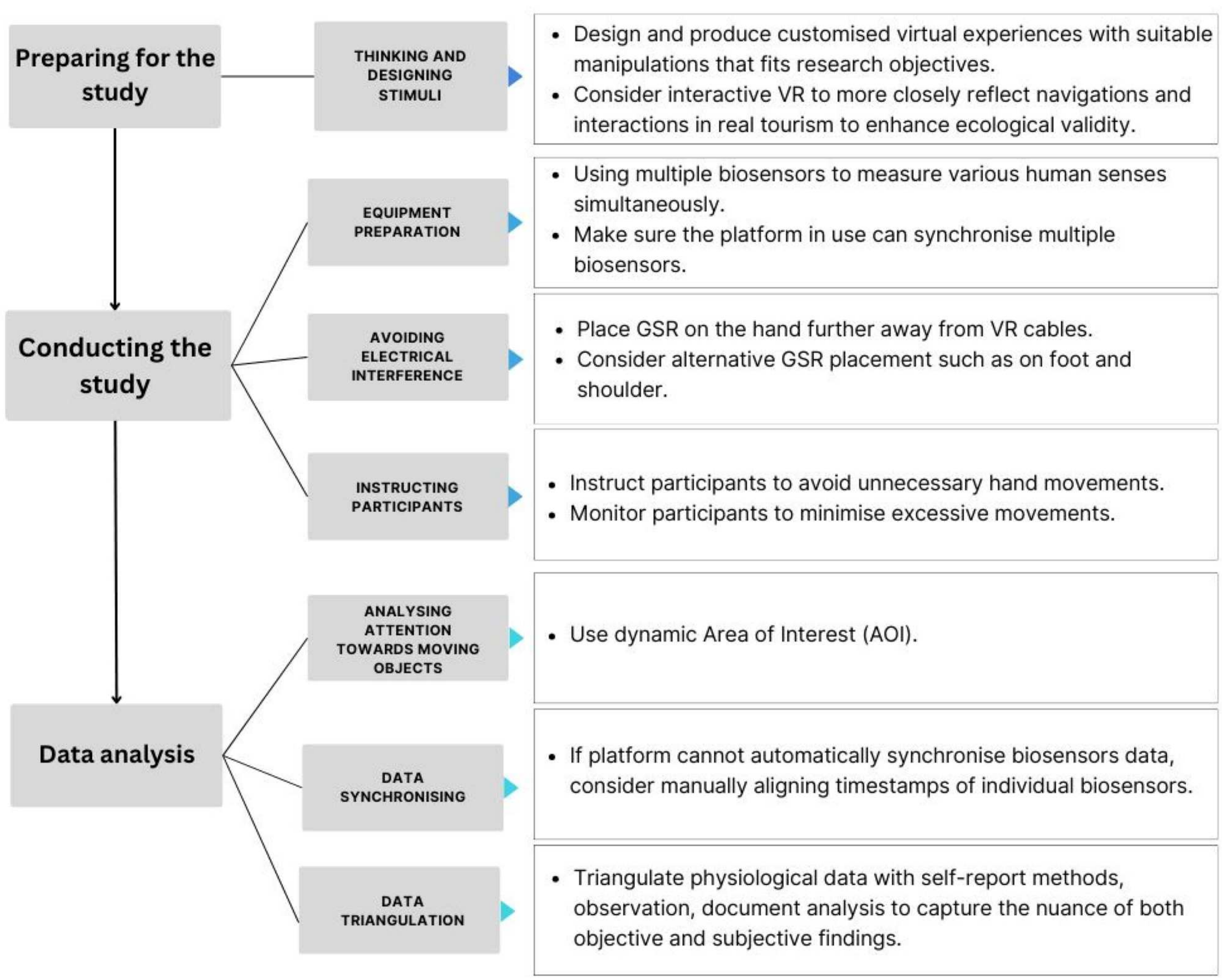

Figure 2. Three-step road map for caveats application.

In Step Two, Conducting the Study, it is critical to address challenges regarding equipment preparation. Researchers should use multiple biosensors to measure different human senses simultaneously and check whether their platform can automatically synchronise multiple biosensors. When conducting studies, it is also important to minimise electrical interference by positioning GSR sensors on the hand away from VR cables and potentially purchasing specialised equipment to place this sensitive equipment on the foot or shoulder. It is also important to instruct participants prior to starting the experiment and monitor them to minimise unnecessary hand movements.

In Step Three, Data Analysis, researchers should apply dynamic AOI to analyse attention towards moving objects. Synchronising biosensor data is also crucial, either automatically or manually by aligning the timestamps of individual biosensors if necessary. Finally, data triangulation is recommended, comparing physiological data with data from self-report methods, observations, and document analysis to capture the nuance of both objective and subjective insights.

Concluding remarks

The aim of this manuscript was to present a series of considerations for future researchers seeking to apply physiological measurement techniques in virtual tourism research. The paper advances existing discourse in VR tourism literature by presenting three caveats critical for researchers applying the emerging physiological measures in VR tourism. Even though physiological methods are more objective than self-report methods in analysing VR tourism experiences, it certainly does not mean that self-report methods are 'dead' and should be dismissed. Scholars should combine physiological methods with traditional methods to harmonise the objective and subjective findings to achieve a more nuanced understanding of user experience with VR tourism.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Anna Kralj is an Associate Professor in the Department of Tourism and Marketing, Griffith University, Australia. Her research interest is the tourism and hospitality workforce, with a particular interest in service management, organisational behaviour and human resources management. Before joining academia, Anna had an extensive career in the hotel industry at a management level. Anna's professional experience is primarily in food & beverage operations and human resource management.

Brent Moyle is a Professor in the Department of Tourism and Marketing, Griffith University, Australia and a visiting Professor in the School of Tourism and Hotel Management, the Hong Kong Polytechnic University. Brent takes an interdisciplinary approach to tourism research, partnering with researchers and communities to maximise outcomes. His passion for sustainable regional development laid the foundations for a number of long-term collaborations with local government and parks agencies. He has published over 100 manuscripts in top tourism journals, with a focus on tourism, regional development, sustainability and the visitor experience.

Biqiang Liu is a PhD candidate in the Department of Tourism and Marketing, Griffith University, Australia. He earned his Master's degree from the School of Tourism Management at Sun Yat-sen University in 2020. He has published over 25 articles in esteemed journals and engaged in multiple research grants in Australia and internationally. His current research explores the intersection between tourist experiences and tourism marketing, with an interest in immersive technologies (e.g. virtual reality) and demonstrated expertise in physiological measures (e.g. eye tracking, galvanic skin response and facial expression analysis).

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