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ENHANCING ATTENDEE ENGAGEMENT IN VIRTUAL AND HYBRID EVENTS: THE ROLES OF TECHNOLOGY AND DATA ANALYTICS

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ABSTRACT

The rapid growth of virtual and hybrid events has increased the need to better understand how digital technologies influence attendee engagement. This study examines the roles of technology and data analytics in enhancing attendee engagement in virtual and hybrid event settings. Drawing on a socio-technical perspective, the study explores how technology supports data analytics and how both contribute to attendee engagement. Data were collected from participants who had attended virtual or hybrid events in Malaysia and analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The findings show that both technology and data analytics have significant positive effects on attendee engagement. However, data analytics has a stronger influence than technology, suggesting that while reliable digital infrastructure is essential, the effective use of data plays a greater role in creating engaging event experiences. The results also indicate that technology significantly supports data analytics, highlighting the importance of integrating both elements in virtual and hybrid event management. These findings offer practical guidance for event organisers by emphasising the need to combine reliable digital platforms with effective data analytics to improve attendee engagement. The study also contributes to the event management literature by demonstrating how technology and data analytics work together to support meaningful and sustainable engagement in virtual and hybrid events.

Keywords: Virtual event, hybrid event, data analytics, event technology, attendance engagement

INTRODUCTION

In today's service economy, the tourist and event sectors are crucial because they foster social connection, cultural exchange, economic growth, and destination branding (Getz & Page, 2019). Rapid technological advancements and changing guest expectations have caused major changes in the event sector over the last ten years (Petrovic et al.; Bladen et al., 2022). By upending conventional event delivery and promoting the use of digital technology, the COVID-19 epidemic hastened this transition even more (Seraphin, 2021; Chibaya & Zhou, 2023). Many events around the world were canceled or postponed due to travel restrictions, health issues, and movement control measures, which caused significant financial losses for venues, destinations, and organizers (Rouhi Khorasani, 2021). According to Amankwah-Amoah et al. (2021), virtual and hybrid events have developed as viable options that enable organizers to continue organizing events through digital platforms while accommodating minimal physical attendance. Virtual and hybrid events are now seen as crucial components of the long-term growth and sustainability of the event industry rather than just as short-term fixes.

In addition to the rise in virtual and hybrid events, digital technology and data-driven decision-making have become more and more important to event planners. Artificial intelligence (AI), augmented reality (AR), virtual reality (VR), wearable technology, the Internet of Things (IoT), and sophisticated connectivity systems are some of the technologies linked to the Fourth Industrial Revolution that have revolutionized the planning, execution, and experience of events (Ivanov et al., 2013; Khan, 2022). These technologies facilitate real-time communication, personalized experiences, and interactive material, especially in virtual contexts where in-person engagement is scarce. Digital technologies have a beneficial impact on attendee happiness, perceived value, and engagement, according to earlier research (Chodor, 2020; Bukovska et al., 2021; Gordon-Bennett, 2023).

Data analytics has grown in importance as an event management tool in tandem with advancements in digital technologies. Organizers can gain a better understanding of the behaviors, preferences, and engagement patterns of attendees by gathering data from social media, mobile applications, registration systems, and tracking technologies like Radio Frequency Identification (RFID) before, during, and after an event (Hernandez, 2016; Freeman, 2019). Personalized event experiences, more focused marketing, and improved event performance evaluation are all made possible by these data (Eventbrite, 2019). Because attendee behaviors can be tracked and analyzed in real time, data analytics becomes even more beneficial in virtual and hybrid events where attendees connect through digital platforms.

Studies on virtual and hybrid events are still scarce in a number of crucial areas, despite increased interest from scholars and practitioners. Technology features, digital platforms, and the wider digital revolution of tourism and event management have been the primary subjects of previous research (Getz & Page, 2019; Cobanoglu et al., 2021). Similarly, research on data analytics has mostly focused on its function in marketing, ROI, and operational effectiveness (Orlando, 2021). These studies show the usefulness of data analytics for event management, but they don't fully explain how data analytics affects attendees' participation in virtual and hybrid events. Additionally, the cognitive, emotional, and behavioral aspects of attendee engagement are frequently studied as a result without providing a thorough explanation of how technology and data analytics interact to influence the overall event experience (Bietz et al., 2022). As a result, not enough research has been done on the connection between technology, data analytics, and attendee engagement, especially when it comes to virtual and hybrid events.

Event planners now face a significant problem as a result of the industry's quick digital transition. Despite organizations' ongoing investments in data analytics and new technologies, there is still a dearth of actual data demonstrating how these expenditures increase attendee engagement. Organizers of many virtual and hybrid events still have to deal with issues including poor post-event engagement, little contact, diminished attention, and few networking opportunities. These problems mean that merely implementing new technology does not guarantee an improved event experience.

It is still unknown which technological elements have the biggest impact on attendees' cognitive, emotional, and behavioral engagement, despite the fact that technologies like artificial intelligence (AI), virtual networking platforms, augmented and virtual reality (AR/VR), and interactive applications are now frequently employed in event design. Previous research has mostly discussed these technologies and how they work without going into detail on how they affect attendees' experiences (Chodor, 2020; Bukovska et al., 2021). Because of this, event planners frequently have little data to help them decide how best to allocate their resources.

Similar to this, while data analytics is becoming more widely acknowledged as a crucial tool for decision-making, its impact on attendance engagement from the participant's point of view has not received enough attention. Prior research has mostly concentrated on customer segmentation, marketing performance, and return on investment (Orlando, 2021). It has paid less attention to whether personalized content, real-time feedback, and behavioral data enhance attendee engagement and participation in virtual and hybrid events.

Lastly, despite their tight collaboration in practice, technology and data analytics are frequently studied independently. Data analytics assists event planners in interpreting the data produced by technology and utilizing it to enhance the event experience. In hybrid events, where organizers must simultaneously manage both physical and virtual audiences, this link is especially crucial (Nilsson, 2020; Sakovets, 2023). Nevertheless, little research has looked at how data analytics and technology interact to affect audience engagement. Closing this gap leads to a more thorough comprehension of participation in virtual and hybrid event environments.

This study investigates the connections between technology, data analytics, and attendee engagement in virtual and hybrid events in Malaysia in order to fill in these research gaps. The study specifically looks at how technology and data analytics affect attendee engagement and how technology facilitates the application of data analytics to improve the entire event experience. Based on these objectives, the study seeks to answer the following research questions:

- (1) How does technology influence attendee engagement in virtual and hybrid events in Malaysia?
- (2) How does data analytics influence attendee engagement in virtual and hybrid events in Malaysia?
- (3) What is the relationship between technology and data analytics in shaping attendee engagement in virtual and hybrid events?

In hybrid events, where organizers must simultaneously manage both in-person and virtual attendees, the difficulty is much higher. Regardless of how guests enter the event, they must guarantee efficient communication, equitable opportunities for involvement, and a consistent experience. Differences in participation between in-person and virtual attendees may result from poorly integrated technology or ineffective data analytics, which lowers the event's overall quality and value (Legkau & Tichaawa, 2022). Therefore, ensuring that technology and data analytics collaborate to provide meaningful and long-lasting attendee engagement is more important than just implementing digital technologies.

In light of this, the main research issue is not only the paucity of studies on the subject but also the absence of conclusive empirical data regarding the ways in which technology and data analytics affect attendee engagement, both separately and collectively, especially from the viewpoint of attendees in a developing event destination like Malaysia. Without this knowledge, event planners can make significant investments in digital technologies without knowing which ones actually increase attendee engagement. As a result, three relevant research issues are addressed in this study: (1) the limited empirical understanding of how technology influences attendee engagement; (2) the underexplored role of data analytics in enhancing attendee engagement; and (3) the limited understanding of how technology and data analytics work together to influence attendee engagement in virtual and hybrid

events. These research problems form the basis for the research questions and hypotheses examined in this study.

LITERATURE REVIEW

Virtual and Hybrid Events in Contemporary Event and Tourism Studies

Over the past ten years, tremendous technological advancements and worldwide disruptions like the COVID-19 epidemic have significantly altered the event business. In the past, events were planned as in-person get-togethers where people interacted, shared experiences, and met in person at a particular location (Getz & Page, 2019). These in-person contacts added to the social and economic value of events and constituted a significant portion of the entire event experience. This conventional approach was disrupted by the COVID-19 epidemic. The popularity of virtual and hybrid formats has accelerated due to travel constraints, health concerns, and prohibitions on public gatherings, which forced event organizers to investigate new means of delivering events (Amankwah-Amoah et al., 2021; Seraphin, 2021). While hybrid events combine in-person attendance with online involvement via integrated technology, virtual events enable participants to participate completely through digital platforms that facilitate communication, networking, and interaction (Nilsson, 2020). Despite the fact that these formats were first implemented as useful reactions to the epidemic, they are now a crucial component of long-term event planning and business growth.

Hybrid events are becoming more widely acknowledged as a significant innovation that boosts industry resilience, promotes sustainability, and increases potential to reach larger audiences from the perspectives of tourism and event management (Legkau & Tichaawa, 2022). Hybrid events enable organizers to engage attendees who would not be able to travel due to time, money, or geographic constraints by mixing in-person and virtual involvement. They can also lessen the environmental effects of travel and, in certain situations, cut operating expenses.

Even with these benefits, hybrid event management is still difficult. While managing two participation environments at once, organizers must provide a consistent and captivating experience for both on-site and virtual participants (Ansah et al., 2023). Because of this, the success of hybrid events rests not just on the technology's accessibility but also on how well it facilitates engagement and connection. Organizers are able to track attendee behavior, customize event experiences, and sustain engagement throughout the event thanks to dependable digital platforms, user-friendly interfaces, and efficient use of data analytics.

Even though there is a growing body of literature on event digitalization, empirical research is still mostly focused on a small number of geographical contexts. In Western nations, especially in Europe, North America, and Australia, where digital infrastructure is more advanced, technological literacy is typically higher, and digital participation is well-established, the majority of research on technology adoption and attendee engagement in virtual and hybrid events has been carried out. These studies frequently make the assumptions of reliable internet access, high levels of technological proficiency, and individualistic participation patterns that prioritize self-motivation and autonomous engagement.

These circumstances might not accurately represent the technological, sociological, and cultural realities of developing Southeast Asian travel destinations like Malaysia. Malaysia's event atmosphere is shaped by social relationships, peer interactions, and community participation, all of which may have varied effects on attendee engagement because the country is a multicultural nation with stronger collectivist beliefs. Additionally, how participants use digital platforms and react to data-driven engagement methods may vary depending on their access to technology and degree of digital

confidence. As a result, straight application of engagement models created in Western contexts to Malaysia may ignore significant contextual variations. To comprehend how technology and data analytics affect attendee engagement in Malaysia's changing virtual and hybrid event landscape, further empirical research is required.

Attendee Engagement in Virtual and Hybrid Events

Attendee Engagement

Because it captures how attendees perceive and react to an event, attendee engagement has grown in importance in event and tourism research. Cognitive engagement, emotional engagement, and behavioral engagement are the three main characteristics of engagement, which is widely acknowledged as a multifaceted notion. Attendees' focus and mental effort during an event are referred to as cognitive involvement. While behavioral engagement is exhibited through actions like participation, interaction, and content sharing, emotional engagement shows users' sentiments like enjoyment, enthusiasm, and attachment.

Direct interaction, shared experiences, and the environment established by individuals congregating in one location inherently foster these forms of participation in conventional face-to-face events (Getz & Page, 2019). However, when events are presented in virtual or hybrid formats, it becomes more difficult to sustain participation. Participants' level of involvement may be lowered by distractions, technical difficulties, and fewer chances for impromptu participation (Bietz et al., 2022). Therefore, it takes more than just moving a live event to an online platform to create meaningful interaction in virtual and hybrid events. Throughout the event, event planners must create digital experiences that actively promote involvement, communication, and continuous engagement.

In technology-mediated settings, social presence has been emphasized by academics as a critical component in fostering attendee engagement. The degree to which participants view others as "real," accessible, and psychologically attached during digital conversation is known as social presence (Bietz et al., 2022; Sakovets, 2023). Digital communication is more successful when participants experience a sense of intimacy, immediacy, and connection, according to Social Presence Theory. This can be more challenging to accomplish in virtual and hybrid events when attendees are not physically present in the same place. Therefore, careful planning and efficient use of digital technology are necessary to preserve meaningful contact.

Event planners are increasingly using interactive elements like audience response systems, live chat, real-time polling, breakout networking sessions, and high-quality audio and video streaming to improve their social presence. Participants feel more connected and actively participated during the event thanks to these elements that promote communication not just between organizers and attendees but also among attendees themselves. Maintaining audience engagement in virtual and hybrid event settings requires creating these chances for interaction.

Interactive technologies provide participation opportunities, but they may not always result in significant attendee involvement. According to research, adding more digital features does not ensure a better event experience. In certain situations, attendees may become overwhelmed, lose focus, and experience cognitive fatigue due to excessively complicated technology or having to manage several digital platforms during hybrid events. A number of contextual elements, such as participants' digital literacy, the platform's usability, and their prior experience with digital communication tools, all have an impact on attendee engagement. These elements imply that technology cannot fully account for participation in virtual and hybrid events. Rather, it is influenced by how technology infrastructure, event planning, and participants' proficiency with digital devices interact. Thus, it is still crucial to conduct study on how technology and data analytics interact to affect attendee engagement. This is

especially important in developing event locations like Malaysia, where levels of technical access, digital preparedness, and engagement behaviors might be different from those seen in Western research.

Virtual and Hybrid Contexts

According to recent research, keeping attendees engaged at virtual events is typically more difficult than at traditional in-person events. Distractions include multitasking, frequent interruptions, and extended screen time can cause participants in online events to lose focus and develop "screen fatigue" (Ramely et al., 2021). Virtual environments offer less social and sensory clues to keep attendees interested than physical events, where the location, ambience, and in-person interactions organically encourage involvement. When many organizations swiftly moved their activities online during the COVID-19 outbreak, these difficulties became much more noticeable. Even while digital platforms made it possible for events to continue, many organizers just moved their pre-existing programs online without making any changes to accommodate the various expectations and behaviors of virtual audiences. Because of this, attendees frequently turned into passive spectators rather than active participants, which diminished the interactive and experiencing element that is essential to successful events.

Because organizers must simultaneously provide a favorable experience for two distinct groups of attendees—those visiting in person and those participating virtually hybrid events provide additional obstacles (Ansah et al., 2023). The incident is frequently seen differently by these two groups. Face-to-face networking, impromptu interactions, and the environment produced by being physically there are all advantageous to participants. Virtual participants, on the other hand, rely heavily on digital communication tools, which can offer fewer chances for face-to-face communication and deep social connections. Remote attendees could therefore feel less engaged in the event than those who are present in person. Some researchers describe this as a "participation divide," where virtual attendees perceive themselves as secondary participants rather than fully engaged members of the event. Organizers must carefully incorporate technology by offering synchronized communication channels, engaging digital platforms, and events that promote connection between participants in person and virtually in order to reduce this gap. These tactics enhance participant happiness, perceived value, and future participation intentions while fostering a more inclusive event experience.

These difficulties demonstrate the necessity of doing more than just using digital platforms to broadcast events. Rather, hybrid events ought to be thoughtfully planned to promote communication, involvement, and shared experiences between participants who are there in person and those who are not. In order to accomplish this, suitable technology must be used in conjunction with efficient data analytics to comprehend participant engagement throughout the event. Organizers may better understand attendees' needs and make timely modifications throughout the event with the use of real-time engagement statistics, behavioral insights, and participant feedback. By utilizing this information, event planners can modify interactive activities, communication, and content to make both in-person and virtual attendees' experiences more engaging. Nevertheless, despite the growing interest in technology-supported engagement, there is still a dearth of empirical data elucidating the ways in which technology and data analytics interact to affect attendee participation in hybrid events. This emphasizes the need for greater study to fully comprehend how these tools might be applied to produce more engaging, inclusive, and participatory event experiences.

Technology in Virtual and Hybrid Events

In the context of the event industry, technology refers to the digital tools, processes, and infrastructure that facilitate the planning, execution, interaction, and assessment of events (Petrovic et al., 2015).

Technology is more than just an auxiliary tool in virtual and hybrid events. It has a major influence on how attendees feel about the event as a whole. Artificial intelligence (AI), augmented reality (AR), virtual reality (VR), 5G connectivity, the Internet of Things (IoT), wearable technologies, and other Fourth Industrial Revolution-related technologies have opened up new possibilities for more immersive and interactive event experiences (Ivanov et al., 2013; Khan, 2022).

A helpful explanation of how technology affects audience engagement is given by the Stimulus–Organism–Response (S-O-R) framework. This idea holds that people's behavior is influenced by their internal psychological reactions to external stimuli (Mehrabian & Russell, 1974). Technology functions as these external stimuli in virtual and hybrid events by influencing attendees' sense of enjoyment, immersion, and interaction. Throughout the event, these satisfying encounters promote more participation.

According to earlier research, event technologies improve attendee engagement through immersive experiences, personalized material, and real-time interactivity (Chodor, 2020; Bukovska et al., 2021). For instance, richer visual and sensory experiences produced by augmented reality (AR) and virtual reality (VR) make virtual events more memorable and captivating (Al-Ansi et al., 2023). Similarly, during virtual and hybrid events, 5G connectivity facilitates seamless streaming and real-time engagement, assisting organizers in keeping guests' interest and involvement (Tummala et al., 2025).

The results of the survey also demonstrate that both participants and event planners understand how crucial technology is to producing memorable event experiences. According to Gordon-Bennett (2023), 68.9% of organizers said that event software was necessary for effective event management, and over two-thirds of attendees enjoyed mobile applications because they promoted interaction during events. These results imply that technology is a significant factor in promoting attendance participation. By increasing interaction, bolstering social presence, and improving the overall event experience, technology is anticipated to have a beneficial impact on attendee engagement, in line with the Stimulus–Organism–Response (S-O-R) framework and prior empirical research. This logic leads to the following hypothesis being put forth:

H1: Technology has a significant positive influence on attendee engagement in virtual and hybrid events.

Data Analytics and Engagement Enhancement

The methodical gathering, examination, and interpretation of data to aid in decision-making and enhance event performance is known as data analytics. Data is gathered from a variety of digital sources in the event business, such as social media platforms, mobile applications, registration systems, and tracking technologies like Radio Frequency Identification (RFID) (Hernandez, 2016). These statistics offer important insights into the traits, inclinations, participation trends, and level of involvement of attendees during an event. Digital analytics, in contrast to conventional post-event surveys, enables event planners to track attendee behavior in real time and make prompt modifications to enhance the experience (Freeman, 2019). In virtual and hybrid events, where participant interactions continuously produce digital data, this capacity is especially useful.

Theoretically, data analytics helps event planners better understand the requirements and expectations of participants, which promotes value creation (Eventbrite, 2019). Organizers may make well-informed decisions about event programs, communication tactics, and platform features to increase attendee engagement by analyzing data such as session attendance, interaction levels, and content performance. Additionally, prior research has demonstrated that analytics facilitates more individualized event experiences and targeted marketing. For instance, social media analytics tools like Google Analytics, Facebook Insights, and Instagram Insights assist event planners in determining the kinds of material

that encourage more interaction from attendees (Nanda & Kumar, 2021). Similarly, RFID technology enables event planners to track attendees' movements and involvement in real time, facilitating tailored suggestions and better crowd control (Hernandez, 2016).

Despite the widespread recognition of these benefits, very few studies have looked at how data analytics directly affects participants' engagement. The majority of prior research has concentrated on organizational outcomes like return on investment and operational efficiency, paying little attention to how data-driven practices affect participants' experiences at virtual and hybrid events. Data analytics is anticipated to have a beneficial impact on attendee engagement due to its capacity to facilitate personalization, prompt responses, and ongoing enhancement of the event experience. As a result, the hypothesis that follows is put forth:

H2: Data analytics has a significant positive influence on attendee engagement in virtual and hybrid events.

Relationship Between Technology and Data Analytics

In virtual and hybrid events, technology and data analytics are intimately related. Large volumes of data are produced by digital technologies, and data analytics assists in turning that data into information that is helpful for decision-making, event planning, and attendee engagement (Cobanoglu et al., 2021). For instance, data analytics are used by artificial intelligence (AI) platforms to personalize content, while attendee engagement data is used by event organizers to enhance interactive elements and participant experiences.

Socio-technical Systems Theory, which emphasizes the significance of matching technology with organizational and human demands, can be used to explain this relationship. In the context of an event, technology offers the digital infrastructure that facilitates communication and data gathering, while data analytics assists organizers in interpreting the data and utilizing it to enhance the experiences of attendees. Technology and data analytics work together to promote better decision-making and engagement tactics.

Previous studies suggest that technology alone may not achieve its full potential without According to earlier research, technology might not reach its full potential without the efficient application of data analytics (Freeman, 2019). Similarly, without dependable technology solutions for data collection and management, data analytics cannot offer significant insights. This complementary relationship emphasizes how crucial it is to incorporate data analytics and technology into virtual and hybrid events. It is anticipated that technology and data analytics will have a substantial positive association based on the literature now in publication. As a result, the following hypothesis is put forth:

H3: Technology has a significant positive relationship with data analytics in virtual and hybrid events.

METHODOLOGY

Research Design

Based on a deductive methodology, this study uses a quantitative, cross-sectional, explanatory research design. Because the study intends to employ statistical modeling approaches to experimentally investigate the hypothesized links between technology, data analytics, and attendee engagement, a quantitative design is acceptable (Sekaran & Bougie, 2016). In order to investigate causal linkages and evaluate theory-driven hypotheses, quantitative approaches are frequently employed in tourism and event management research, especially when the constructs can be quantified using standardized research instruments (Getz & Page, 2019).

The study used a cross-sectional design, collecting data from participants all at once. Because events take place within a certain time frame, it is feasible to record attendees' opinions soon after their involvement, which is why this method is frequently employed in event and tourism research (Hair et al., 2019). Therefore, without the necessity for longitudinal data collection, a cross-sectional methodology is appropriate for investigating attendee engagement, data analytics, and technological impressions in virtual and hybrid events.

Instead, than merely documenting the occurrence, this study aims to explain variances in attendee involvement based on technological and analytical aspects, which makes it explanatory in character. This strategy is in line with earlier research on event management that looks into variables affecting experience and behavioral results (Legkau & Tichaawa, 2022). Using a deductive methodology, the study develops hypotheses based on existing theories and prior empirical findings, which are subsequently tested with empirical data.

Instrument Development and Measurement

A structured self-administered questionnaire created by modifying validated measuring scales from earlier studies referenced in this study was used to gather data. Respondent profile, technology, data analytics, and attendance engagement were the four primary elements of the questionnaire. A five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"), was used to measure each topic. Because they enable respondents to express varying degrees of agreement and are ideal for multivariate statistical analyses, such as structural equation modeling, Likert scales are frequently employed in tourism and event management research (Sekaran and Bougie, 2016; Hair et al., 2019).

In order to make the measurement items applicable to virtual and hybrid event settings in Malaysia, a few minor phrasing adjustments were required. In particular, each construct's original meaning was maintained while the items were reworded to reflect digitally mediated involvement. When measuring scales created in various geographic or event contexts are used in a novel study setting, this method is in line with accepted quantitative research standards (Sekaran and Bougie, 2016).

The technology construct assessed respondents' opinions on the usefulness and efficiency of technical tools such as digital platforms, interactive features, and connectivity quality used in virtual and hybrid events. According to Petrovic et al. (2015), Ivanov et al. (2013), and Khan (2022), the measuring items represented how technology might improve engagement, accessibility, and the overall event experience. In order to investigate the impact of emerging technologies including 3D printing, 5G technology, artificial intelligence (AI), and augmented reality (AR) on attendee participation in virtual and hybrid events, the items were modified from Aktepe & Demirci (2024).

Respondents' opinions on how data-driven techniques, like tailored content delivery, feedback systems, and engagement tracking, enhanced their event experience were gauged using the data analytics construct. The measurement items were modified from research that highlighted the importance of analytics in evaluating event performance and participant involvement (Hernandez, 2016; Freeman, 2019). Instead of using analytics for organizational purposes, small contextual adjustments were made to represent the viewpoint of the attendees. In order to investigate how data-driven practices affect attendee engagement in virtual and hybrid events, the items were further modified from Orlando and Lin (2020) using analytics technologies including Facebook Insights, Twitter (X) Analytics, Google Analytics, and Radio Frequency Identification (RFID).

The dependent variable in this study, attendee engagement, was operationalized as a multidimensional construct that reflected behavioral, emotional, and cognitive involvement during the event. In line with earlier engagement research, the measuring items evaluated respondents' attention, interaction, participation, and perceived involvement during virtual or hybrid events (Bietz et al., 2022; Sakovets,

2023). The elements, which were modified from Mehrotra and Lobo (2020), captured aspects including greater event accessibility in virtual and hybrid event settings, stronger online presence, increased brand awareness, and improved attendee experience.

By carefully modifying measurement items from well-known literature and making sure they were in line with the study's conceptual framework, content validity was proven. In accordance with typical instrument development procedures in tourism and event management research, the questionnaire was also examined to make sure it was clear, relevant, and consistent with the constructs being studied (Sekaran and Bougie, 2016).

Sample and Data Collection

People who had taken part in virtual or hybrid events hosted in Malaysia made up the study's target demographic. Malaysia was chosen as the study location due to its expanding status as a new event destination and the rising popularity of virtual and hybrid event formats. Because respondents had to fulfill a particular requirement that is, had previously participated in at least one virtual or hybrid event, a purposive sampling technique was used. In tourism and event management research, purposeful sampling is frequently employed when the study concentrates on participants with pertinent experience and expertise (Getz and Page, 2019). This strategy made sure that participants could offer well-informed assessments of attendee engagement, data analytics, and technology use.

In order to offer a profile of the sample and support the interpretation of the results, descriptive analysis of the respondents' demographic characteristics such as gender, age group, education level, and frequency of participation in virtual or hybrid events was done using SPSS. In tourism and event management research, descriptive statistics are frequently used to characterize sample characteristics and improve study transparency (Sekaran and Bougie, 2016).

Data Screening and Preliminary Analysis

The data were reviewed using SPSS to make sure they were accurate and appropriate for multivariate analysis before hypothesis testing. The methods used for data screening adhered to accepted standards for quantitative research (Hair et al., 2019). First, we looked at the missing data. There were very few missing values in the dataset, and in order to preserve data quality, cases with a lot of missing data were eliminated. The use of forced-response settings helped reduce incomplete responses because the questionnaire was administered online.

Second, normality was assessed using skewness and kurtosis statistics. As commonly observed in social science and tourism research, some variables did not meet the assumption of normality. However, this does not pose a problem because PLS-SEM does not require multivariate normality (Hair et al., 2019). Third, outliers were examined using standardised scores and boxplots. No extreme outliers were identified that would significantly influence the parameter estimates. Overall, these screening procedures confirmed that the dataset was suitable for subsequent PLS-SEM analysis.

Data Analysis Technique

To investigate the suggested theories, this study used partial least squares structural equation modeling (PLS-SEM). PLS-SEM is a variance-based structural equation modeling method that assesses the measurement model and the structural model at the same time (Hair et al., 2019). The suggested PLS-SEM procedures were followed in a two-stage analysis of the data. Indicator reliability, internal

consistency reliability, convergent validity, and discriminant validity were first evaluated using the measurement model. Second, the path coefficients, coefficient of determination (R²), and significance of the suggested hypotheses were examined in order to assess the structural model.

While PLS-SEM software (as used in the thesis) was utilized for model estimation and hypothesis testing, SPSS was utilized for preliminary analyses, such as descriptive statistics and data screening. Because SPSS facilitates data preparation and PLS-SEM software is used to assess theoretical models and research hypotheses, this combination is frequently utilized in tourism and event management research (Hair et al., 2019).

RESULTS

Descriptive Statistics

Descriptive statistics were examined to give a general picture of the respondents' demographic profile and the distribution of the study constructs before hypothesis testing (Table 1). In accordance with established quantitative reporting procedures in tourism and event management research, the descriptive analyses were carried out using SPSS (Sekaran and Bougie, 2016).

Participants who have attended at least one virtual or hybrid event in Malaysia made up the sample. The sample was sufficiently diversified to examine perceptions of technology use, data analytics, and attendee engagement because respondents represented a wide variety of age groups, educational levels, and event attendance frequencies. There was less chance of demographic bias because the gender distribution was comparatively fair.

Table 1

Respondent demographic profiles

Gender	Total	Percentage
Male	168	59%
Female	116	41%
Total	284	100%
Age		
Less than 20	28	10%
21 – 25 years old	99	35%
26 – 30 years old	71	25%
31 – 35 years old	28	10%
36 – 40 years old	23	8%
41 – 45 years old	17	6%
46 years old and above	18	6%
Total	284	100%
Education		
Secondary level	43	15%
Diploma	71	25%
Bachelor	114	40%
Postgraduates	43	15%
Professional and others	13	5%

Total	284	100%
Marital status		
Single	170	60%
Married	99	35%
Separated	15	5%
Total	284	100%
Occupation		
Government	57	20%
Private	114	40%
Retired	14	5%
Students	99	35%
Total	284	100%
Race		
Malay	199	70%
Chinese	43	15%
Indian	28	10%
Others	14	5%
Total	284	100%

Regarding the utilization of technology and data analytics in virtual and hybrid events, respondents generally expressed moderate to high levels of agreement. Additionally, they showed positive levels of attendee engagement, indicating that most participants said they were emotionally, behaviorally, and cognitively engaged throughout the events they attended. A respectable degree of consistency in the responses was shown by the standard deviation values, which were within acceptable levels. These descriptive results justify additional PLS-SEM analysis and offer initial evidence for the significance of technology and data analytics in influencing attendee engagement.

Measurement Model Assessment

Prior to testing the structural model, the measurement model's validity and reliability were evaluated using Partial Least Squares Structural Equation Modeling (PLS-SEM). The evaluation adhered to the recommendations made by Hair et al. (2019). Indicator reliability was confirmed since all indicator loadings were higher than the suggested cutoff of 0.70. Both Cronbach's Alpha and Composite Reliability scores were more than 0.70, indicating the establishment of internal consistency reliability. Since every Average Variance Extracted (AVE) value was more than 0.50, convergent validity was verified. The Fornell-Larcker criterion and the Heterotrait-Monotrait Ratio (HTMT) were also used to establish discriminant validity; all HTMT values were below the suggested cutoff of 0.85. All things considered, these findings show that the measurement model attained acceptable degrees of validity and reliability.

Structural Model Assessment

The structural model was evaluated to investigate the proposed links between the constructs once the measurement model was validated. Following the suggested PLS-SEM procedures, the evaluation

concentrated on path coefficients, explanatory power (R^2), effect sizes (f^2), predictive relevance (Q^2), and model fit indicators (Hair et al., 2019).

According to Hair et al. (2019), the bootstrapping method was used to assess the structural model. The findings supported H1 and H2 by demonstrating that both technology and data analytics significantly improved attendee engagement. Additionally, technology significantly improved data analytics and supported H3. Attendee engagement's R^2 value showed a moderate level of explanatory power. The model's predictive relevance was validated by the Q^2 values, and the effect sizes (f^2) varied from small to medium. Furthermore, a satisfactory model fit was shown by the Standardised Root Mean Square Residual (SRMR) value being less than 0.08. Overall, the results show that, when it comes to virtual and hybrid events, the suggested model has adequate explanatory and predictive power.

DISCUSSION

Interpretation of Key Findings

This study looked into how technology and data analytics affected Malaysian attendees' participation in virtual and hybrid events. All three hypotheses are strongly supported by the results, which also offer insightful information on how digital technologies affect attendee engagement in modern event settings. Overall, the findings demonstrate how crucial data analytics and technology are to producing more captivating virtual and hybrid event experiences.

The results supported Hypothesis 1 by demonstrating that technology significantly increases attendee engagement. This outcome is in line with earlier research that emphasizes how crucial technology is to producing dynamic and captivating event experiences (Petrovic et al., 2015; Chodor, 2020; Bukovska et al., 2021). Technology is more than just a medium for content delivery in virtual and hybrid events. Additionally, it allows attendees to engage, communicate in real time, and participate meaningfully. The results corroborate previous research indicating that interactive platforms, high-quality streaming, and integrated digital tools improve attendees' behavioral participation, emotional engagement, and cognitive attention (Ivanov et al., 2013; Khan, 2022).

These results are also in line with the Stimulus-Organism-Response (S-O-R) paradigm and Social Presence Theory, which contend that technology aspects affect how guests perceive and react to an event. The results show that participants increasingly evaluate the quality of virtual and hybrid events based on the efficiency and usefulness of the offered digital technology, which is consistent with Gordon-Bennett (2023). Technology helps generate a deeper sense of presence and connection in hybrid events, when virtual participants may have fewer possibilities for in-person engagement. This encourages attendees to stay actively involved throughout the event.

Additionally substantiated was Hypothesis 2, which suggested a favorable correlation between data analytics and attendance engagement. This result is in line with earlier research emphasizing the advantages of data analytics in event management (Freeman, 2019; Hernandez, 2016). The current study demonstrates that attendees also recognize the significance of data analytics in improving their event experience, despite previous studies mostly focusing on the function of analytics in improving marketing activities and organizational performance. Participants get a more relevant, interesting, and responsive event experience thanks to data-driven strategies including tailored material distribution, flexible scheduling, and feedback systems.

These results imply that data-informed event design is increasingly influencing attendee participation in virtual and hybrid events. According to Eventbrite (2019), data analytics helps organizers better understand the preferences and behavioral patterns of attendees, enabling them to provide more relevant and personalized event experiences. By showing how data analytics improves attendee engagement in

virtual and hybrid events, the study's findings add to the body of research and corroborate these insights from the viewpoint of the attendees.

Additionally supported was hypothesis 3, which looked at how technology affected data analytics. The results indicate that successful data analytics in virtual and hybrid event contexts are based on efficient technologies. This lends credence to the idea that data analytics and technology collaborate closely rather than operating independently. Data analytics assists organizers in processing and interpreting the important attendance data produced by digital platforms including registration systems, virtual conferencing tools, and interactive applications in order to enhance attendee engagement and support decision-making. The capacity to gather, handle, and analyze event data would be constrained in the absence of dependable IT infrastructure.

These results are in line with the Socio-technical Systems Theory, which highlights how crucial it is to match organizational procedures with technological systems. The digital infrastructure for the current study is provided by technology, and data analytics assists in turning the information gathered into insightful knowledge that facilitates event planning and participant engagement. Strong analytics capabilities is dependent on well-designed and integrated technological systems, according to the substantial relationship between technology and data analytics. To enable more efficient virtual and hybrid event management, investments in data analytics should be paired with ongoing enhancements to digital infrastructure.

When considered collectively, these results imply that attendee engagement in virtual and hybrid events depends not just on the technologies employed but also on how well data analytics and technology collaborate to facilitate meaningful interactions. The platform is made possible by technology, and data analytics enables event planners to better understand participants and enhance their experience over time. When combined, they make virtual and hybrid events more interesting and participant focused.

Theoretical Implications

This study adds significantly to the literature on tourism and event management in a number of ways. First, it demonstrates how data analytics and technology have an impact on audience participation in virtual and hybrid events. While other research has acknowledged the significance of technology in influencing event experiences (Getz & Page, 2019; Petrovic et al., 2015), this study shows that data analytics is more than just a managerial tool; it also directly improves attendee engagement.

Second, the results validate the use of the Stimulus–Organism–Response (S-O-R) paradigm in hybrid and virtual event environments. The findings imply that data analytics and technology function as external stimuli that affect attendees' internal reactions, including their sense of social presence, involvement, and relevance. Higher levels of audience involvement are subsequently encouraged by these internal reactions. This study shows that the S-O-R framework is still a helpful theoretical framework for comprehending attendee involvement in digitally mediated event contexts by offering empirical support for these links. By doing this, it addresses requests for additional empirical research in tourism and event management that is grounded in theory (Legkau & Tichaawa, 2022).

Third, by demonstrating that attendee involvement in virtual and hybrid events depends not just on communication technologies but also on how organizers employ data analytics to enhance the event experience, this study also advances Social Presence Theory. Data analytics allows organizers to tailor material, address attendees' needs, and foster more meaningful interactions during the event, while communication platforms facilitate connections between attendees. These results imply that social presence is enhanced not just by communication itself but also by data-driven event planning that increases participants' sense of involvement and connection (Bietz et al., 2022; Sakovets, 2023).

Finally, by presenting data from Malaysia, a setting that has gotten comparatively little attention in event technology research, this work adds to the expanding corpus of research on virtual and hybrid events. Malaysia, one of Southeast Asia's newest event locations, provides insightful information about how data analytics and technology affect attendee engagement in a different cultural and business context. The study shows that current engagement theories are applicable outside of Western and industrialized nations and addresses calls for more geographically diversified tourism and event management research by analyzing these links in the Malaysian setting.

Practical and Managerial Implications

The study's conclusions have a number of useful ramifications for destination managers, event planners, and legislators who oversee virtual and hybrid events. First, rather than just being an operational expense, technology should be seen as a strategic investment. The positive correlation between technology and attendee engagement implies that participants' total event experience is directly impacted by the caliber of digital platforms, internet access, and interactive elements. As a result, event planners should make investments in dependable and user-friendly technology that promote social presence, communication, and involvement during the event. For virtual guests, whose entire event experience hinges on the caliber and efficacy of the digital platform, this is especially crucial.

Second, the results emphasize how crucial it is to incorporate data analytics into all phases of event preparation and execution. Organizers should use real-time data to assess participant engagement and make timely adjustments throughout the event, rather than relying solely on analytics after it has concluded. For instance, depending on attendance' reactions and engagement levels, organizers can change the program's timetable, add more interactive activities, or alter the event's topic. This makes it possible for organizers to provide a more engaging event experience and react to attendees' needs more swiftly.

Third, rather than depending on disparate platforms that don't interact with one another, event planners should implement integrated digital systems due to the close relationship between technology and data analytics. Organizers may track participant involvement more efficiently and make well-informed decisions throughout the event by combining registration systems, event platforms, communication tools, and analytics into a single solution. Additionally, an integrated approach helps organizations maximize their technical expenditures while providing guests with a more seamless and captivating experience.

Fourth, virtual and hybrid events can be used by destination managers and policymakers to increase the competitiveness of destinations and boost the industry's resilience. Destinations like Malaysia can draw more inventive, accessible, and globally connected events by investing in digital infrastructure and fostering the advancement of technical capabilities. This is especially crucial as many travel locations are still creating post-pandemic tourism plans that blend in-person and online interaction.

Lastly, the results emphasize how crucial it is for event professionals to acquire digital capabilities. Effective use of technology and data analytics is contingent upon event planners possessing the necessary skills and self-assurance to implement them. Therefore, in addition to embracing new technology, training programs, professional development initiatives, and industry norms should assist practitioners in using data to enhance attendee engagement and the entire event experience.

Limitations

This study contains a number of limitations that should be taken into account when interpreting the results, notwithstanding its contributions. First, examining changes in attendee involvement over time

is limited by the cross-sectional research design. Attendees' opinions and experiences may vary throughout the course of an event because data was gathered at a specific moment in time.

Second, this study used self-reported data, which could be impacted by social desirability bias or common method bias. Respondents' views may not always accurately reflect their actual behavior during virtual and hybrid events, despite the use of established measuring scales and suitable data screening techniques.

Third, Malaysian virtual and hybrid events were the study's main emphasis. As a result, the results could not be immediately applicable to other nations or different kinds of events, where cultural, technological, and commercial circumstances might change. Lastly, even though the suggested model showed adequate explanatory power, there are numerous additional elements that affect attendee engagement that were outside the purview of this study, including event content, speaker caliber, program design, and personal motivation.

Future Research Directions

Several avenues for further investigation are proposed, building on the limitations of this work. First, to investigate how attendee involvement varies before to, during, and following virtual or hybrid events, future study could use a longitudinal research design. Stronger proof of causal linkages and a greater understanding of how involvement changes over time would result from such an approach. Second, by adding more variables like pleasure, perceived value, and behavioral goals, future studies could expand the suggested model. By taking these factors into account, it would be possible to better understand how attendee engagement affects significant outcomes like loyalty, positive word-of-mouth, and inclinations to return.

Third, it would be possible to ascertain whether the results are applicable in various event settings and cultural contexts by conducting comparative research including various locations or event kinds, such as festivals, conferences, exhibitions, and sporting events. Fourth, by integrating quantitative analysis with qualitative observations or interviews, future research could use a mixed-methods approach. This would assist explain why some technology and data-driven practices have a greater impact on engagement than others and offer a deeper insight of participants' experiences. Lastly, as digital technologies develop further, future studies should examine how new developments like artificial intelligence (AI), immersive technology, and sophisticated data analytics affect attendee engagement and influence the direction of virtual and hybrid events.

CONCLUSION

This study looked at how participants' perceptions of technology and data analytics affect their participation in virtual and hybrid events. The results demonstrate the critical roles that data analytics and technology play in producing memorable event experiences. Instead of considering data analytics as a tool for organizational decision-making or technology as merely a platform for delivering events, this study shows that both directly influence attendees' cognitive, emotional, and behavioral involvement. These results offer a more comprehensive picture of how, in today's event sector, digital transformation may improve attendee experiences.

The study also discovered that the best results come from combining technology and data analytics. Data analytics lets organizers better understand participants' demands and continuously enhance the event experience, while technology offers the digital platform for connection. This emphasizes how crucial it is to use technology and data-driven decision-making to produce virtual and hybrid events that are more interesting and significant. The results are especially pertinent in the post-pandemic setting,

where organizations are expected to prove the worth of their digital expenditures and hybrid events have established themselves as a component of the travel and event sector.

Lastly, this study adds to the expanding body of knowledge on virtual and hybrid events from a Southeast Asian viewpoint by presenting evidence from Malaysia. The results demonstrate that the connections between technology, data analytics, and attendee engagement are also pertinent in a developing event destination, offering more proof outside of the Western settings that predominate in the majority of the body of existing literature. Overall, this study shows that technology opens doors, but how well technology and data analytics work together to support attendees throughout the event experience determines how significant attendee involvement is.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTION STATEMENT

Abd Shukor, S. contributed to the research design, data interpretation, and manuscript editing. Md Sharif, N. supervised the research, reviewed and revised the manuscript. Mohd Nazari, N. conceptualized the study, collected and analysed the data, and prepared the first draft of the manuscript. All authors read and approved the final version of the manuscript.

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