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"Easy to join in your pyjamas": benefits and barriers of online science engagement at Australia's 2020 National Science Week

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Abstract
In 2020, National Science Week events shifted online in response to Australian COVID-19 restrictions. Our research captures this rapid pivot from in-person to online science events, exploring experiences through audience and presenter questionnaires, and follow-up interviews. We examine characteristics of audiences for online science events, benefits and barriers of these events, and opportunities for online engagement. Key benefits were ease of attendance, new experiences enabled online, and greater control and flexibility. Lack of social interaction, technology issues, and audience reliability were identified as barriers. Our research suggests online events operate in a different sphere to in-person events and informs the delivery of engaging online experiences.

Introduction
Science festivals are an increasingly popular avenue for public engagement with science, and are growing in number [Bultitude, McDonald and Custead, 2011; Science Festival Alliance, 2018]. These events typically occur in-person, but in 2020, the COVID-19 pandemic resulted in many science events and festivals rapidly moving online, alongside similar transitions in education, entertainment, and social events. This shift provided new opportunities for engagement, but also highlighted the challenges of delivering events online. Previous research on online science engagement has predominantly focused on social media platforms such as Twitter [Côté and Darling, 2018], Facebook [McClain, 2017], and YouTube [Erviti and Stengler, 2016; Kohler and Dietrich, 2021]. To date, there has been limited research on online science events delivered by science communicators.

Two recent studies into online science events have investigated audience and presenter motivations and preferences. Research into live-streamed science debates in Germany found four distinct audience segments, each with different reasons for attending and preferences in engagement styles [Wicke and Taddicken, 2020]. A 2019 study found that U.K. science communicators showed a preference for in-person events, stating that online events lacked the social context of in-person events. However, the participants of this study acknowledged that these attitudes may change over time as technology and familiarity advance [Fogg-Rogers et al., 2019].

Beyond these initial studies, there is little data on experiences of online science events, and the characteristics of audiences who attend. Research into online experiences in formal education are more widely explored, and some comparisons can be drawn from online education. Studies have demonstrated student preferences for in-person over online learning [Lee et al., 2021], with isolation and lack of peer interaction identified as barriers for online learning [Croft, Dalton and Grant, 2010]. Many educators report difficulties in moving their teaching online, citing the additional emotional work involved in adopting pedagogical approaches for online learning environments [Bennett, 2014; Naylor and Nyanjom, 2021]. However, factors such as previous experience with online learning [Wang, Shannon and Ross, 2013], and confidence in using the required technology [Aguilera-Hermida, 2020] improved student experiences of online education.

Science festival audiences

Previous research of in-person science festivals has found that audiences often share common characteristics [Canovan, 2020]. They tend to be more educated and socio-economically privileged than the general population, and often already have positive attitudes towards science and a personal interest in science [Canovan, 2020]. Science communication efforts and events frequently experience the persistent issue of "preaching to the science choir" [Scheufele, 2018], where those who choose to attend are typically already interested in science [O'Connell et al., 2020]. This pattern holds true for science festival audiences in the U.S. [Nielsen, Gathings and Peterman, 2019; Rose et al., 2017] and the U.K. [Kennedy, Jensen and Verbeke, 2018]. Similar characteristics can be observed for attendees of purpose-built settings, such as science centres [Falk, Storksdieck and Dierking, 2007]. It is also observed at events in more casual and/or social settings, such as pubs [Ocobock and Hawley, 2020] and STEM stand-up comedy [Roche et al., 2020].

Recently, there has been greater emphasis on building science events that attract and serve a more diverse audience, rather than new audiences of the same ilk [Archer et al., 2021; Dawson, 2014]. However, opportunities to engage with science at festivals are not equitably distributed across the population or reaching underserved audiences [Nielsen, Gathings and Peterman, 2019]. This gap can further entrench societal divides, favouring highly educated and economically advantaged groups. A study by Canovan [2019] showed that the parents of families in low socio-economic backgrounds "were disproportionately likely to say attendance had improved their perception of science". The study suggested this is because they may have had fewer opportunities to engage with science and scientists previously. In order to target more diverse audiences, some festivals have

employed strategies to encourage attendance from underrepresented or disinterested groups. Some examples of successful strategies include working with community groups [Canovan, 2020], engaging celebrities to publicise and host events [Chen, 2014], or including science in non-traditional or unexpected locations [Dowell, 2014; O'Connell et al., 2020].

National Science Week in Australia

National Science Week (NatSciWk) is an annual science festival held in Australia, traditionally running in-person in August since 1997 [National Science Week, 2020]. NatSciWk typically hosts numerous events that take place simultaneously across the country. In March 2020, state governments across Australia introduced restrictions in response to the COVID-19 pandemic, and NatSciWk was moved online. This was the first time the majority of NatSciWk events were held online, with 627 of 1,211 total events occurring online in 2020, compared to just 23 in the previous year. COVID-19 necessitated a rapid pivot to online, and as noted by Hodges et al. [2020] within the context of science education, there is a difference between the emergency remote teaching necessitated during COVID-19, versus carefully planned and tested online learning. We suggest the same could be said for science event presenters in 2020. Nonetheless, it provided a unique opportunity to explore a science festival and its audience in an online context.

Objectives

This study aimed to address the identified gap in the literature of experiences of online science events delivered by science communicators. It investigated the audience characteristics of online science festivals, and identified benefits and barriers for audiences and presenters of online science events to help inform science communication practice. The investigation centred on three key research questions:

1. What are the characteristics of audiences engaging with online events during National Science Week? (RQ1)

2. For both audiences and presenters, what are the commonly perceived benefits and barriers of online events compared to face-to-face events? (RQ2)

3. What forms of engagement do online events enable that traditional face-to-face events do not? (RQ3)

Methods

To address our research questions, we used NatSciWk 2020 as a case study for online science events. Creswell and Poth [2018] define a case study as an exploration of "a real-life, contemporary, bounded system through detailed, in-depth data collection involving multiple sources of information". This approach enabled us to construct an in-depth understanding of experiences of online science events from the perspectives of audiences and presenters within the context of NatSciWk 2020.

Research tool development overview

Questionnaires were used to collect data from a larger sample size, with interviews used to explore identified themes from the questionnaire data in greater detail.

Audience and presenter questionnaires (see project GitHub page: https://github.com/alintheopen/SCOPE/issues/10) developed by the researchers were based on questionnaires administered by Inspiring Australia (IA) during previous National Science Weeks in Australia. The questionnaires were adapted to address our research questions. Both questionnaires were moderated internally by the authors and evaluated by external researchers. The audience questionnaire was also piloted on volunteer members of the public, who were provided a YouTube video exploring a scientific concept to watch as their 'online event'. Interview questions were refined after preliminary analysis of the questionnaire data by two researchers, and then moderated by other members of the research team.

All participants in the study were informed that their participation was voluntary, anonymous, and that they were free to withdraw at any time. All procedures were approved by the University of Sydney's Human Research Ethics Committee regulations (project number: 2020/508).

Questionnaires

Recruitment and data collection

Data were collected during NatSciWk using two online questionnaires: one for audiences, and another for presenters. The audience questionnaire was directly emailed to registered participants for participating events, and the presenter questionnaire was distributed through IA. Links to participate in this study were also circulated on social media. The questionnaires opened on August 15 and closed on Oct 10. This timeframe enabled researchers to capture online events launched during NatSciWk, as well as related events occurring after NatSciWk. A total of 720 audience records and 107 presenter records were collected. Incomplete records and responses that described in-person events were removed, yielding 611 audience records and 88 presenter records.

Data analysis

Descriptive analysis was used for demographic data and close-ended questions for both audience and presenters. The socioeconomic status of attendees was approximated by comparing postcodes with average median income by postcode from the financial year 2018–2019 from the Australian Tax Office. Data analysis was conducted by two authors (OM and ED) unless stated otherwise.

Open-ended data from the questionnaires were analysed using thematic analysis [Braun and Clarke, 2006]. An inductive approach was used to identify unique or unexpected perspectives within the data, with two authors independently coding 10% of the audience data with 50% overlap. Identified themes were discussed to establish agreement. This iterative process was used to develop codebooks for the two open-ended question (enjoyment and online format), which were reviewed and discussed by all five authors to ensure consensus. Two authors then independently coded 5% of the audience sample using the codebook for the online format question, which contained 11 codes overall. These samples were then compared for agreement (where both researchers coded a response the same way) and discrepancies (where researchers had coded a response differently). This was

used to calculate Cohen's kappa in SPSS and validated through manual calculation (example calculations are on the project GitHub page, https://github.com/alintheopen/SCOPE/issues/10). This yielded Cohen's kappa (κ) = 0.87, indicating strong agreement [McHugh, 2012]. The same process was used to establish intercoder reliability for the codebook used for the audience enjoyment question (κ = 0.81). These finalised codebooks were used to analyse the remaining audience data.

For presenters, there was one open-ended question about the online format. Two authors independently coded 22% of the presenter responses to this question and discussed them to establish a set of agreed codes. The whole dataset was then coded independently by two authors according to these codes, with strong agreement (κ = 0.84) followed by a discussion to resolve any inconsistencies.

Interviews

Recruitment and data collection

Follow-up interviews were conducted with 22 audience members and 17 presenters throughout October and November 2020. All audiences and presenters who had consented to contact by the researchers were emailed. Participants were selected from those that expressed interest to ensure they represented a variety of events and experiences.

Data analysis

Interviews were analysed through thematic analysis using NVivo Qualitative Data Analysis Software (QSR International Pty Ltd. 2018). Building on themes identified from the questionnaires, a set of codes exploring the barriers and benefits of online events were used to analyse interview data from both audiences and presenters. Two audience interviews and one presenter interview were coded independently by the two authors, followed by discussions to refine and add relevant codes identified in the data. The interview codebook was checked by all five authors to ensure agreement. Three additional interviews were independently coded by two authors and compared (κ = 0.87). The remaining interviews were coded independently.

Limitations

First, this study was not designed to explicitly capture online experiences impacted by COVID-19. However, experiences of online events during NatSciWk 2020 cannot be extracted from the impacts of COVID-19. As such, the results reflect an unplanned rapid pivot to online for most online events. The authors would also like to note that not all events included in this study were delivered live. This allowed exploration of the full potential of the online space for science engagement, of which pre-recorded outputs formed an important part.

Second, median incomes were estimated by matching postcodes to income data from the Australian Tax Office. This is in line with methods used in previous

research [Nielsen, Gathings and Peterman, 2019]. However, the authors recognise there are limitations in estimating incomes this way, considering the large disparities in income in some postcodes. As such, it is an indicator of the median income of audiences only.

Finally, our audience reflects a small sample of audiences who attended NatSciWk, with IA estimating participation in NatSciWk 2020 topped 100,000. These participation rates include in-person events, but were not collected as part of this study. Most of the responses collected were from the eastern Australian states and territories for both audiences and presenters, particularly from New South Wales, making it difficult to get an accurate nationwide picture of NatSciWk. However, given the frequency across the dataset of the identified themes, this data does present a snapshot of some common experiences of online science events from study participants.

Results and discussion

Questionnaires

Questionnaire responses provided data to help investigate audiences of online science events versus in-person science events. Some initial data were also collected on the benefits and barriers, as well as overall impressions of online events. These initial data are discussed below, and informed the direction of follow-up interviews.

What are the characteristics of audiences engaging with NatSciWk?

Our data shows that 82% of surveyed audiences had a tertiary qualification, compared to 43% of Australians aged 25–64 [Australian Institute of Health and Welfare, 2021]. The estimated median income of surveyed audiences was AUD$46,377 p.a., which is slightly below the national median of AUD$49,805 [Australian Taxation Office, 2022], indicating that audiences were not necessarily of a higher than average socio-economic status.

NatSciWk audiences also overwhelmingly demonstrated positive attitudes to science, suggesting they held strong pro-science attitudes prior to attending. As shown in Figure 1, audiences gave very high ratings when asked about the importance of science to society and their personal interest in science, with 95% and 86% respectively giving ratings of 80 or more out of 100. Overall, as shown in Figure 1A and 1B, audiences see science as valuable and interesting. Additionally, 53% of the audience reported spending more than five hours per week on average engaging with science-related topics. Those interested in science are more likely to spend time actively seeking science information [Schäfer et al., 2018] and finding reliable scientific information may therefore motivate audiences to attend NatSciWk.

Interestingly, 61% of audience respondents indicating they had not previously attended NatSciWk. Additionally, 76% of surveyed presenters indicated that they had engaged new audiences during their event. However, there were no observable differences of note between new and old audiences across the questions about science attitude shown in Figure 1A. Similarly, when asked for their level of
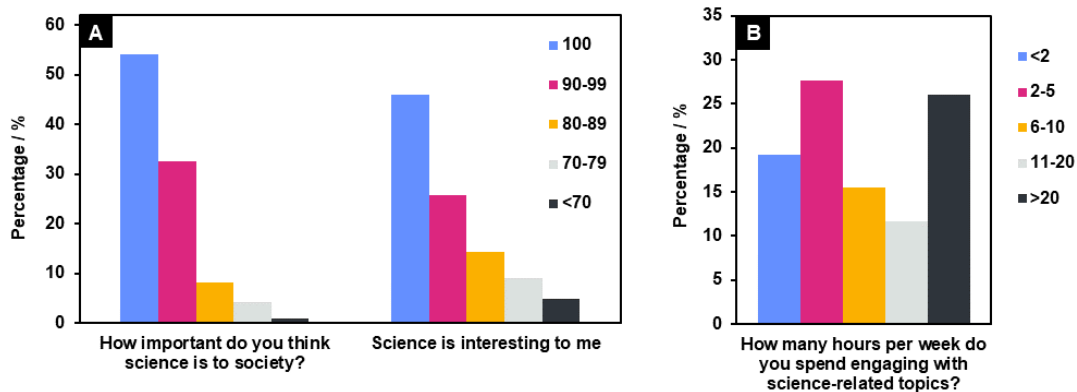
Figure 1. Quantitative data collected from audience questionnaires about attitudes and interest in science and average amount of time spent engaging with science per week. 1A shows questions about the attitudes towards science of NatSciWk audiences, answered on an integer scale from 0–100, where 0 indicated strongly disagree and 100 indicated strongly agree. 1B shows how many hours NatSciWk audiences spend engaging with science each week on average.

education, over 80% of respondents from both groups reported having a tertiary qualification. This suggests that these NatSciWk audiences were new, but not different. One difference between these groups corresponded to the amount of time spent on science per week, where 64% of previous attendees indicated they spent more than five hours on science per week, compared to 46% of first-time audiences. This difference could be attributed to the ease of attending online events, allowing them to work around other time constraints or responsibilities that prevented attendance to in-person events. New audiences may have also sought new experiences that aligned with their interests during restrictions and lockdowns.

Previous literature on science festivals has not addressed internet access and technological literacy, as they were predominantly in-person events. It was evident when examining online science events that this inequity acutely impacted experiences. Questionnaire data found both audiences (12%) and presenters (18%) reported internet and other connectivity issues as a barrier to a positive online experience. We suggest our collected data underrepresents connectivity issues in Australia, as people without access to the internet or persistent issues with connectivity are less likely to register for or present an online event. In Australia, rural areas tend to be more digitally disadvantaged than metropolitan areas, and low socio-economic status, low education levels, and lack of confidence with digital technologies are also significant barriers to digital participation [Park, 2017]. Our data likely represents the subset of people who believed they had sufficient resources and skills to sign up for an online event, and still experienced complications.

Overall, this data shows that both new and returning audiences tend to be highly educated and demonstrate pro-science attitudes. This suggests that these new audiences are not "different audiences" compared to typical science festival audiences, as this group overall still matches the archetype [Nielsen, Gathings and Peterman, 2019]. Our data suggest that online science festivals attract audiences with similar characteristics to those reported from in-person science festivals. This highlights that the online format alone does not inherently attract

underserved audiences or those outside the group Scheufele [2018] described as the "science choir".

Benefits of online events — findings from questionnaires

Questionnaire data revealed benefits of online science events but lacked sufficient detail about the challenges. Barriers were explored further in follow-up interviews, discussed in the *Interview* section. Full details of audience and presenter questionnaires can be found on the project GitHub page: https://github.com/alintheopen/SCOPE/issues/10#issuecomment-1080244336.

When audiences were asked what they enjoyed the most, comments about "good presenters" were the most common (31%), closely followed by liking a specific feature of the event (30%), such as a demonstration or Q&A section. Of the 30% coded into this theme, the most common subtheme was two-way interaction with scientists (38%). Personal interest in the topic was also frequently mentioned in enjoyment (24%).

Responses from audiences on the online format were categorised into positive, negative, or neutral responses, shown in Figure 2. This analysis demonstrated that 82% of respondents said the online format positively influenced their decision to attend. 1% of respondents said it had a negative influence, with the remainder giving neutral responses or insufficient information. Where further details for preference of online events were given, responses were coded into categories. The top five categories are shown in Figure 2.

The most common reasons given by audiences who preferred online was the convenience of the online format (for example, that it was "*easy to join in your pyjamas*"). This convenience was mentioned by 25% of respondents, encapsulated
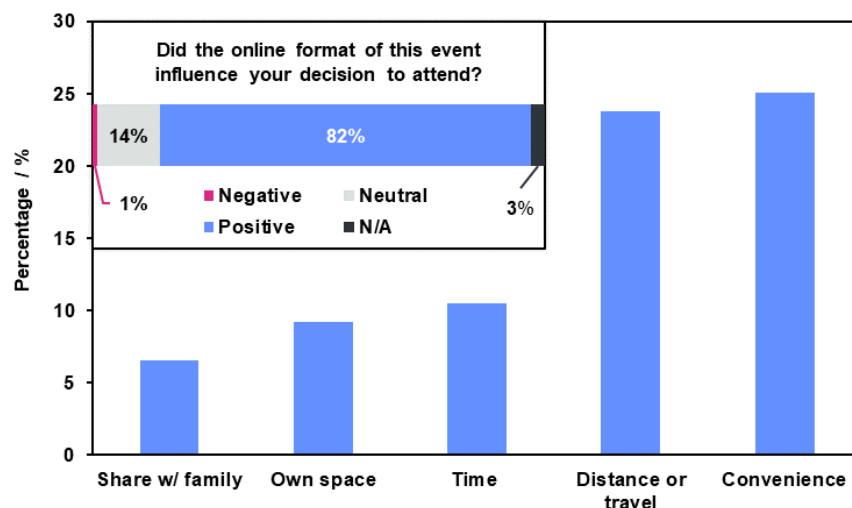

Figure 2. Summary of the most common reasons the online format had a positive influence on audience attendance. The inset shows all responses coded to either a positive, neutral, or negative influence on attendance. 3% of responses gave insufficient information to code to one of these categories, and is represented by N/A.

by one audience member: *"It's so much easier to dial into a talk from my home and I'm more willing to attend talks that I wouldn't ordinarily attend"*.

The ability to attend without travelling was highlighted by 24% of audiences. This enabled attendance from overseas or interstate audiences, and more participation from regional audiences. (*"Being in a regional area, normally events like these are held in city centres with live audiences and I can't get time off work and travel to attend."*) Even within metropolitan areas, audiences often stressed how time-consuming or difficult it is to travel to CBD locations, especially without a personal vehicle. Presenters also viewed the reduced need for travel for both themselves, fellow presenters, and their event audiences as a positive, and a reason to present online (see project GitHub page: https://github.com/alintheopen/SCOPE/issues/10#issuecomment-1080244336). For these presenters, the ability for online events to reach national or international audiences was appealing: *"I wanted to showcase around Australia and online was the way to do it!"*

Other positive benefits identified by audience were flexibility of the events (11%), the ability to participate from comfort of their own homes (9%) and the ability to involve family members in the event (7%).

For many presenters, the pivot presented an opportunity to evolve their practice, be inventive, and contribute to future engagement. As one presenter summarised: *"It has allowed us to rethink delivery methods and content… to develop a new product, virtual incursions, that we had previously not explored"*.

Of the 56% of presenters who were influenced to present because of the online format, 29% referenced the potential for "new opportunities" for event development and delivery, and a further 23% stated their event was only possible in an online context. Strong commitment from presenters to deliver events that worked online, even if it meant redesigning their event from scratch at late notice, resulted in positive audience experiences.

Interviews

Preliminary analysis of the questionnaire data and the benefits of online science events informed the direction of the interviews and allowed more detailed examination of the benefits and barriers. Interview questions also interrogated forms of engagement enabled by online science events as compared to in-person. A total of 39 interviews were conducted, and reported frequencies are inclusive of both presenter and audience interviews unless stated otherwise.

Benefits: the potential of online events

The digital platforms used during NatSciWk this year enabled different forms of engagement compared to face-to-face delivery. Attendees of NatSciWk, delivered August 2020, had potentially already developed a familiarity with many online platforms during the first months of COVID-19 restrictions. This knowledge potentially reduced their resistance towards online events [Aguilera-Hermida, 2020; Levordashka et al., 2021] with familiarity perhaps supporting positive

Table 1. Themes from interview data describing the benefits of online events. Themes mentioned by at least 16 of the 39 participants (audience and presenters) are included but are presented separately to reflect their different experiences. Sub-themes are not included.

Theme	Example quote	Audience (n = 22)	Presenter (n = 17)
Easier to attend	*I've got a primary school child and for me to get out is not easy... so to be able to just listen at home is much easier. — Audience*	20	15
Online enabled different modes of delivery and interaction	*The ability to put little comments and chats in the side at the same time as well... it allowed for more engagement between the teams than I would see at a traditional trivia event. — Audience*	19	15
Control over personal environment	*I just find online really comfortable as well, because you don't have to get dressed up and go out. You can just be in whatever and chill out on your bed or whatever, and watch the event. — Audience*	17	8
Involvement from broader audiences/ presenters	*Each video has 200 to 400 views, which is a lot more engagement than we would get in a physical event, which is really cool. — Presenter*	7	15

experiences with events, with 33 participants explicitly mentioning enjoyment. Benefits that contributed to enjoyment and positive experiences are shown in Table 1, highlighting how online events could transform science engagement experiences.

The ease of attending and presenting online events compared to in-person events was the most frequently mentioned theme in the dataset, with 35 interviewees highlighting this aspect. This again mirrors the benefits expressed in the questionnaire data, where factors such as convenience, time commitment, and the distance were all evident. Within the interview data, distance was the largest sub-theme (26 times), followed by time (20 times), accessibility (16 times) and financial access (13 times). Distance also overlapped with time and financial access for many, as summarised by one participant:

> *It was a massive saving in terms of time, because [it's] an hour trip there and hour trip back, and the fuel and the cost of running a car for a hundred odd kilometres.*
> *— Audience*

The financial savings resulting from not having to pay presenters for travel was also identified as a benefit by several presenters:

> *[In 2019] we had a person from Perth and a person from Melbourne and we paid for their flights, which takes up a big bit of the budget. So, I guess if it's online, you can sort of expand your pull, because you're not having to pay travel for people.*
> *— Presenter*

The ability to involve broader audiences was mentioned by 22 interviewees. It was highlighted more frequently by presenters than audiences, with 15 of the 17

presenters highlighting this benefit compared to 7 audience members. This theme encompassed comments about access to larger audiences (15 times) and the wider geographic reach enabled by the online format (16 times). Geographical reach applied to both audiences and presenters, as presenters living interstate or overseas could participate in events. One presenter described online events as allowing *"a complete unshackling of geographical location"*. Several presenters also reflected that they would use online formats in future to involve people from different locations:

> *Because we were funded by ACT, we used Canberra scientists… moving forward, we could work with scientists from across Australia as well, maybe get a regional researcher, get more diversity in who we're representing as well. Which is a real positive. — Presenter*

Another common theme was the different types of content and interaction that online enabled (34 times). The most common sub-theme within this category (20 times) was being able to use recordings or materials from events afterwards. Audiences focused on the ability to watch events later, whereas presenters referenced being able to repurpose materials from their events:

> *I do think recording things and putting them up… having people be able to access that in the future, I think is a great way of being able to continue to reach people. — Audience*
>
> *What we're doing after each broadcast and each virtual event that we do, is break that down into smaller learning segments. And then we share it with local schools. — Presenter*

Presenters also used tools available within online platforms to engage audiences (11 times). For example, inbuilt polling tools were used to gauge audience understanding of the topic with misconceptions later addressed in the presentation, which one audience member noted is "*something you don't see a lot at a physical presentation*". Another audience member reflected on an event they described as "*really well done*", where participants were sent tasting boxes, and polls were used during the event to get audience reactions to the foods.

Some presenters felt they could be more creative with their events without the limitations of a physical space. As one presenter explained:

> *Because it was a podcast versus a presentation, I was a lot freer to do more creative things. I had musical underlays, I had quotes, I had sound effects… whereas if I had been facing people, I'm kind of restricted to just one level. — Presenter*

Lastly, the theme of having control of your own environment was mentioned in 25 interviews, 17 of which were audience members. The largest sub-theme acknowledged the comfort of attending or presenting events from home (17 times). As one participant explained, the privacy and comfort of online events enabled their attendance:

> *If it had've been in person, I wouldn't have gone. I'm a very, very private person. I hate going anywhere where there are a lot of people. I just don't go. — Audience*

Being at home also allowed audiences to multitask while listening:

> *During the session, I was also cooking dinner for my kids. — Audience*

A further 9 audience interviews referenced non-committal engagement enabled by online events, a sub-theme that was not highlighted by any presenters. Audiences could attend an event they were unsure about, with the guarantee they could leave without being rude. This was underlined by one audience member:

> *Being online, the investment wasn't massive, I could turn up and if it didn't fit the bill of what I was looking for, I could always stop watching. — Audience*

In line with our findings, a study conducted in Germany analysing audiences at live-streamed science debates found that nearly a quarter were not interested in interacting with presenters. Designated as "appreciative listeners", these audiences attended for the purposes of being entertained and informed [Wicke and Taddicken, 2020]. By enabling a more passive form of engagement for online audiences, presenters may be able to reach participants who are not invested enough to attend in-person events. Overall, the ability to engage with audiences in new ways, using tools or approaches facilitated by the online platforms was a prominent benefit for many audiences and presenters.

Barriers: the challenges of online events

While digital events enabled new opportunities for engagement, they also brought barriers. The key themes are shown below in Table 2. The barriers highlight opportunities to improve understanding and delivery of online events.

When reflecting on online events, both audience and presenters noted there was a certain "vibe" missing from online events (36 times). The most common

Table 2. Themes from interview data describing the barriers of online events. Themes mentioned by at least 16 of the 39 participants (audience and presenters) are included but are presented separately to reflect their different experiences. Sub-themes are not included.

Theme	Example quote	Audience (n = 22)	Presenter (n = 17)
The "missing vibe" of online events	*It really doesn't match the vibe [of having] 80 people crammed into a cafe on a Thursday night. — Presenter*	21	15
Technology issues	*I think there was one lecture… the person was on mute and the video or audio didn't play. It was just a bit of a disaster, and it was just lecture style… it's just something you could look up on YouTube. There's no kind of point to it live. — Audience*	17	15
Audience reliability	*We had every event by registration… but people registered and didn't show, you know. — Presenter*	7	11

sub-theme, referenced by 28 interviews, was the "*very dead environment*" of online. Additional sub-themes included a yearning for elements of face-to-face events (20 times), and the negative impacts of online misbehaviours, such as 'trolling' or 'Zoom-bombing' (7 times).

One-way interactions in online events were cited by both audiences and presenters as preventing them from feeling connected, impacting the delivery of and engagement with the event. These sentiments are highlighted in the examples below:

> *The speakers [are] not getting a lot of feedback, they're not getting the laughter or the faces as much... all that interaction that's so important when you're trying to talk to people. — Audience*
>
> *I couldn't tell if the people without their videos on were disengaged. — Presenter*

Both audiences and presenters expressed a yearning for the socialisation and energy of face-to-face events, exemplified by these two quotes:

> *I know you've got face-to-face contact like we have now [on Zoom], but it is so different to the actual nearness of contact. — Audience*
>
> *You have the spirit, you have this sense of excitement before you that's unfolding throughout the day. You're physically brought together in a group. So, you're meeting new people, you're interacting with them, you're sharing that energy. And then of course, when you're actually doing the science, you're touching the science, you're experiencing the science. — Presenter*

This yearning was independent to their enjoyment of the event, with interviewees concurrently citing enjoyment alongside a desire for face-to-face aspects.

Technology issues were another common theme identified by 32 participants. Interestingly, the most common sub-theme was the steep learning curve of adjusting to new online platforms. Many presenters chose to use platforms that became ubiquitous during COVID-19, such as Zoom, building on familiarity they and their audience already had. Although this learning still involved a time commitment prior to NatSciWk, it allowed presenters to adjust their events beforehand, as expressed by one presenter:

> *We had been running classes over Zoom, for our usual dance classes. So, we'd already kind of broken through that, 'Oh, this is weird, or how close do I need to be to the camera', all that kind of stuff. — Presenter*

Alternative platforms to Zoom presented more of a learning curve. One presenter discussed how their choice to use a new platform necessitated a larger time commitment to learn how to use it:

> *There was a bit more to walk through on how to use the platform because I'd never used it before... You could also do it as a Zoom, but I think we're all Zoomed out. So, this was something a bit unique and interesting. — Presenter*

Although presenters found the new platforms challenging, both audiences and presenters expressed confidence that "*next time, we'll be better at it*". Nine interviewees referenced technology issues such as problems with internet connection or a lack of access to devices. Although internet plans can be relatively inexpensive, the upfront cost of buying a digital device can be prohibitive:

> *Not everybody has a functional computer PC and in terms of socio-economic status of your family… you might not have the necessary resources to attend.* — Audience

Audience reliability was also another barrier identified by 17 interviewees. This encompassed several challenges. Presenters noted that audiences did not attend their events live, whereas audiences struggled to remember the event was on, illustrated by these two quotes:

> *The hard part about being online was also knowing whether people would turn up to your events or how they would engage with it. It was much more uncertainty.* — Presenter
>
> *Unless I set alarms, you can easily forget there's something on.* — Audience

Several presenters also noted that the online format made it difficult to reach their target audience, particularly when their events sought to target those with little interest in science. This issue was illustrated by one presenter:

> *[At in-person events] you've got people who want to be there at the pub, or want to be there for the music, they didn't necessarily want to hear the talk. Whereas on Zoom, then the only people who attend are the people who are interested anyway.* — Presenter

Because of the nature of online events, these incidental audiences all but disappeared for these presenters.

Enabled online: understanding online platforms as a new space for science events

The online format enabled several benefits that cannot be achieved at in-person spaces, but facilitating these benefits often produced barriers. Interrogating these links revealed how different events may prioritise different elements to develop and deliver engaging online science experiences. A summary of these links is shown in Figure 3.

Almost 90% of interviewees stated that online events were easier to attend or present. Audiences said that they enjoyed that the events were easy to attend, and flexible enough that they could change their attendance at the last minute with little consequence, like changing travel plans or losing ticket fees. They also enjoyed the "non-committal" environment of online events, where they could join an event and discreetly leave if necessary. These sentiments reflect the agency online spaces give to audiences; they have a lot more control over how and when they engage.
The online format also provided audiences with more choice, by enabling the attendance of inter-state and international audiences to NatSciWk events.
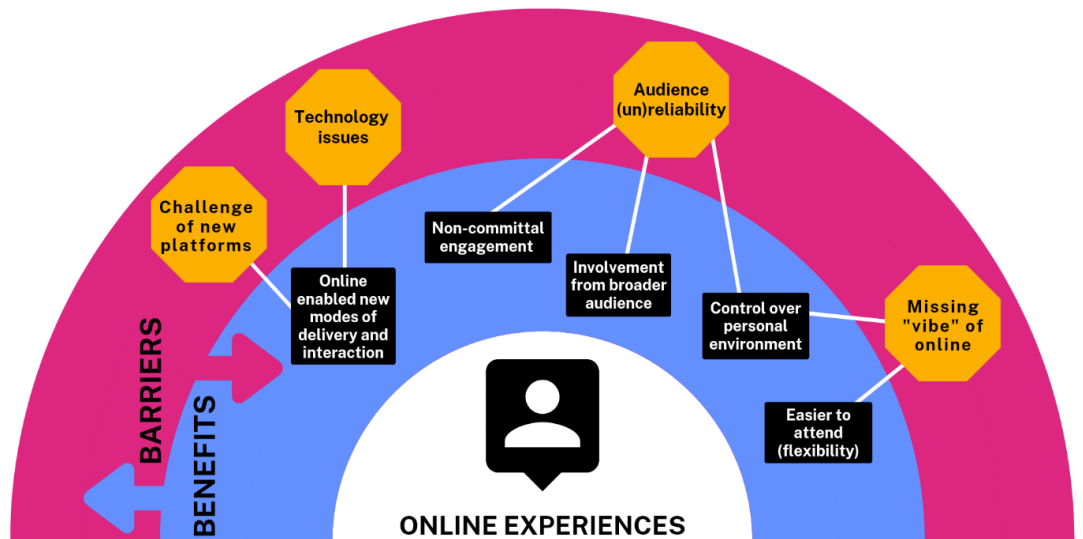
Figure 3. The relationship between some of the benefits and barriers identified for online events.

Presenters also enjoyed the increased flexibility provided by online spaces and new opportunities for engagement. Both audiences and presenters expressed general sentiments of support for online or blended events in the future, demonstrating their willingness to engage with science on digital platforms even if face-to-face delivery returned:

> *I would love it, that in the post-COVID world, that there's still that opportunity to do some online learning.* — *Audience*
>
> *There were things that we will probably incorporate in future science festivals, whether they're constrained by COVID or not, we'll probably build more digital stuff into it.* — *Presenter*

However, the ease of attending and non-committal engagement also meant audiences could be unreliable, as they were more likely to prioritise other responsibilities over the live event, live in different time zones, or forget they had registered. Presenters expressed difficulties with gauging audience numbers, and were disappointed that despite large registration numbers, live events were often poorly attended.

Another feature enabled by the online format was greater autonomy for audiences to choose their engagement style. For those in the non-committal engagement category, this engagement style often looked quite passive, which may have contributed to a sense of audience unreliability or lack of engagement from audiences. However, for many, the online environment gave them greater control over their own personal environment. The ability to turn off cameras in online environments meant that people could meet their own needs without concerns about breaking social norms about what an "attentive" audience member looks like, or distracting other audience members:

> *I have chronic pain issues, so, attending something that's via zoom, particularly if I'm not required to participate and put the screen on, means that I can be moving around,*

doing stretches in the background, moving the desk up and down... doing whatever I need to do to be comfortable. — Audience

Research by Castelli and Sarvary [2021] suggests that in educational settings, students often leave their cameras off because of concerns about their appearance, distracting background environments, or because others also have their cameras off, thereby setting a norm. These factors may also contribute to the preference for cameras to be off during online science events.

Despite audiences enjoying the autonomy the online environment gave them, it also contributed to the missing "vibe" of online for both groups. The norm of having cameras and microphones off during events, or events where only presenters are on-screen, can make it difficult to gauge audience reactions and initiate discussions. Use of tools such as the chat function or polls can help overcome this, but do not replicate the interactions of in-person events.

Technology was also identified as both a barrier and a benefit by audiences and presenters alike. Although online events allowed presenters to create new ways to engage their audience and experiment with new platforms, some audience members and presenters needed to overcome the learning curves associated with new platforms. Technical issues were also pervasive during online events for both presenters and audiences.

The links between some of the common benefits and barriers of online events are not meant as criticism; all events have trade-offs. One audience member reflected that "*the whole thing was inventive*" when thinking about what was achieved in a rapid pivot to online events, highlighting the creativity and ingenuity applied by many presenters when negotiating a new format. However, our findings suggest that presenters should identify priorities for their event(s), and plan accordingly. For example, events which involve audience participation and aim to reach geographically remote audiences may need to rely more heavily on built-in tools, such as polls, or use a platform designed to facilitate audience-presenter interactions. Understanding that online engagement looks different may help presenters anticipate audience behaviours and value the engagement that can extend beyond the "event" itself. The online space also unlocks global audiences who can engage and re-engage with content for an extended period of time. It also gives presenters access to geographically widespread audiences with specific interests, allowing them to better target these groups and provide easy options for follow up content, such as social content campaigns.

Conclusions

This study set out to capture the experiences of online science events delivered by science communicators during NatSciWk. Demographic information of attending audiences were analysed to determine characteristics of audiences of online science events (RQ1). Questionnaires and follow-up interviews provided insights into the barriers and benefits of online events, as expressed by both audiences and presenters (RQ2). Interview questions also explored what was enabled by online science events, that are difficult in face-to-face events (RQ3).

Questionnaire data suggested that NatSciWk audiences demonstrated certain characteristics not reflected in the average Australian population (RQ1). Audiences

were highly educated and had a strong interest and positive attitudes towards science. This is perhaps unsurprising, because, as one presenter put it, "*you don't just stumble across a zoom link. . . you'd have to have seen an advertisement for the event and think, I'm slightly interested in that. I'll come and watch this talk*". As a result, online events tend not to reach beyond the "science choir" and appear to attract a similar audience to in-person science festivals [Nielsen, Gathings and Peterman, 2019]. This does not mean that online events have no potential as an engagement strategy for new audiences. Although audiences shared similar characteristics, over 60% were first-time attendees. It is unclear if approaches used to attract diverse audiences at in-person science events will translate to online events, and more research is needed to address this issue in the online space.

Based on initial data from the questionnaire and further explored through interviews, we identified a number of benefits and barriers associated with online science events (RQ2). Audiences found it easier to attend and appreciated greater choice over how they presented themselves online, if at all. The platforms of online events tend to give users greater autonomy over how they engage, meaning that audience experience is prioritised to some degree in online events. In contrast, barriers related to the lack of social interaction and technological issues, including the challenges of adapting to new platforms. For presenters, a key reservation was that online audiences were perceived as "unreliable".

The benefits expressed by audiences and presenters speak to the ability of online events to deliver unique experiences that can only be facilitated online (RQ3). Understanding how to leverage these benefits while addressing barriers provides insights for science communicators on how to successfully deliver engaging online science events. Our data suggests events considered successful by both audiences and presenters transformed to take advantage of online opportunities, rather than replicating in-person events. Presenters of these events seemed to shift their event expectations for the online space, understanding that engagement would look different to in-person events because audiences have more flexibility to engage and re-engage on their own terms. In future, targeted online science experiences may have the capacity to attract new audiences from geographically diverse spaces, similar to science events held in other non-traditional or unexpected locations [Dowell, 2014; O'Connell et al., 2020].

In most cases, it is not possible to take advantage of the benefits of the online format without also experiencing the challenges, and it is critical that presenters consider the benefits they want to prioritise in online events, and how to address the respective challenges. Through our research, we hope to empower practitioners to take greater advantage of the online format, and shift expectations of online event delivery and engagement. Future research is needed to understand how practitioners can further enhance audience experiences and attract broader audiences to online science events.

To the best of our knowledge, this research contributes the first exploration of the benefits and barriers of online science festivals. In addition to building on the existing literature, this research has already supported practitioners to deliver online science events in 2021 and beyond through continued collaboration with IA.

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