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Shifting from academic air travel to sustainable research exchange: Examining networking efficacy during virtual conferences

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ABSTRACT

Academic conferences are important places for exchanging scientific knowledge and building professional networks, but they also contribute to climate change through emissions caused by air travel. Hence, more sustainable conferences are needed. The unforeseen COVID-19 pandemic presented an opportunity to develop more sustainable conferences by shifting to effective virtual communication. Studies have demonstrated that virtual conferences are often more sustainable, but also more inclusive than in-person conferences, but that they – like in-person conferences – also have drawbacks. Researchers perceive ineffective networking due to a lack of social interaction as the biggest disadvantage of current virtual conferences. This study aims to examine researchers' experiences with virtual conferences by investigating the factors that influence networking efficacy during virtual conferences. To do so, 21 semi-structured interviews were conducted with virtual conference organisers and attendees from various career stages, countries and scientific fields. The input-process-output framework was used to structure the factors that participants mentioned as facilitating or constraining networking. The results demonstrate conference organisers' important role in thinking carefully about technical equipment that facilitates networking and specifically planning virtual conferences' networking sessions. This study is the first to structure factors that influence networking efficacy systematically during virtual conferences. The results of this study revealed that best practice examples of effective virtual networking exist, thus providing a starting point for the shift from academic air travel to more sustainable research exchange.

1. Introduction

Global air travel has contributed around 4% to anthropogenic global warming up to 2019 through CO_2 emissions and non-CO_2 effects (Lee et al., 2021). The air travel sector is characterised by rapid growth, emissions that are hard to abate, and an unequal distribution across the world's population (Gössling and Humpe, 2020; ICAO, 2016; Ueckerdt et al., 2021). Gössling and Humpe (2020) have calculated that a minority of frequent fliers – only about 1% of the earth's population – is responsible for 50% of passengers' air travel emissions.

Academic air travel, which is influenced by predictors such as geographical region and family commitments (Whitmarsh et al., 2020; Wynes et al., 2019), accounts for a considerable share of a university's carbon footprint (Arsenault et al., 2019). Attendance at academic conferences (henceforth, *conferences*), being among researchers' most important travel purposes (Ciers et al., 2018; Wynes et al., 2019), often requires air travel and can "release as much CO_2 as an entire city in a week" (Klöwer et al., 2020, p. 356).

Conferences are an integral part of researchers' academic careers (Rowe, 2018), used to disseminate and exchange scientific knowledge, and to build and maintain networks (Hauss, 2021). Thus, conferences provide opportunities to develop joint collaborations and projects, gain visibility in the academic community, and advance careers (Oester et al., 2017).

In recent years, there have been calls for more sustainable and inclusive conferencing (Neugebauer et al., 2020; Shields, 2019; Whitmarsh et al., 2020). Studies have calculated that virtual conferences (VCs) have the potential of reducing a conference's carbon footprint by over 90%, while hybrid conferences can lead to a reduction of travel emissions by 60–80% compared to in-person conferences (Klöwer et al.,

Abbreviations: IPO, Input-Process-Output; TFOM, The Future of Meetings.

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2020; Tao et al., 2021). Thus, the unforeseen COVID-19 pandemic and, consequently, the rapid shift to virtual communication[1] was viewed as an opportunity to make conferences more sustainable (Moss et al., 2021).

Studies have demonstrated that VCs are more inclusive and lead to a greater diversity in gender, geographic location, and career stages (Le et al., 2020; Skiles et al., 2021), while travelling to in-person conferences excludes disadvantaged groups of researchers (Whitmarsh et al., 2020). VCs are also more accessible to researchers with disabilities, visa issues, care responsibilities and less funding (Huyck et al., 2021; Reshef et al., 2020).

However, VCs also face various challenges, e.g., time zone differences, technical/Internet failures and data security issues (Foramitti et al., 2021; Moss et al., 2021; Schwarz et al., 2020). Furthermore, difficulties maintaining eye contact during virtual communication make it hard to know who wants to speak next (Vertegaal et al., 2003), and staring at a screen can become exhausting and lead to lower attention spans (Moss et al., 2021).

The most prominent disadvantage of VCs is perceived social interaction inefficacy, e.g., spontaneous conversations during coffee breaks, thereby limiting networking opportunities (Foramitti et al., 2021; Wenger, 2022). Although there have been different attempts to incorporate networking into VCs, they have generally not been very successful yet (Raby and Madden, 2021). So far, a systematic analysis of the factors influencing virtual networking's perceived inefficacy is missing. Thus, an investigation is needed into why networking during VCs is viewed as ineffective to better understand the factors that influence networking efficacy during VCs.

This study takes a closer look at researchers' experiences with networking during VCs and examines the following research questions: How do researchers perceive current VCs in terms of their networking efficacy? Which factors influence networking efficacy during VCs? *Networking* is viewed as initiating, building and maintaining a network of social capital through interpersonal processes (Porter and Woo, 2015).

In this research, 21 semi-structured interviews were conducted with researchers in different career stages, countries and scientific fields who have organised and/or attended VCs. This research aims to use the input-process-output (IPO) framework (Hackman and Morris, 1975) to structure the factors interview participants (henceforth, *participants*) mentioned as facilitating or constraining networking during VCs. Thus, this article contributes to science and practice by providing an understanding of the factors that influence networking efficacy during VCs, so that they can be improved in the future to facilitate more sustainable and inclusive research exchange.

2. Literature review on virtual networking: Factors influencing virtual communication

The literature suggests that researchers view networking inefficacy as the main drawback of VCs due to a lack of social interaction and discussions (Foramitti et al., 2021; Wenger, 2022). VC attendees (henceforth, *attendees*) can lack a sense of community because sensory cues, nonverbal communication and a sense of other people are missing (Strengers, 2015). Thus, VCs need to emphasise communication and interaction among attendees and specifically incorporate discussion sessions (Porwol et al., 2022) to facilitate networking. VC organisers play a particularly important role, as they can encourage attendees to engage actively (Roos et al., 2020). Neubauer et al. (2021) stated that VC organisers first should think about the conference's goals (e.g., networking), then realistically plan the conference format based on these goals.

Technical factors, e.g., using suitable virtual tools and platforms, should be considered carefully when organising VCs (Lowell et al., 2022). To mitigate technical issues, other studies have suggested preparing backup options and having technical support staff ready (Porwol et al., 2022; Reshef et al., 2020), and conducting technical rehearsals before sessions to reduce time lost from technical uncertainties (Günther et al., 2021; Neubauer et al., 2021). To allow for greater inclusivity and diversity of attendees, asynchronous and synchronous elements should be used in tandem (Reshef et al., 2020).

Other research has examined factors that highly influence how effective and suitable researchers consider virtual communication. Van de Glind and Gomez-Baggethun (2022) found that researchers view virtual formats as the most effective when social relations already exist, the number of attendees is small and little (creative and social) interaction is required. Other studies similarly found that researchers find it particularly difficult to establish new networks virtually instead of maintaining existing ones (Köhler et al., 2022; Wenger, 2022).

2.1. Virtual teams

Virtual communication between researchers extends beyond conference participation and is important for collaboration on joint research, projects and initiatives. Research conducted in teams has increased significantly (Morrison-Smith and Ruiz, 2020), so I drew on the literature on virtual teams, which has examined virtual teams' benefits and drawbacks compared to in-person teams and analysed the factors facilitating or constraining virtual teams' efficacy (Ale Ebrahim et al., 2009). For example, the literature has found that socialising is an important factor in building trust, satisfaction and team performance (Powell et al., 2004), which can also be leveraged to build or maintain networks.

Research suggests that communication is one of the most important determinants of efficient work in virtual teams (Ale Ebrahim et al., 2009). Team members should have ample opportunities for informal communication (Kilcullen et al., 2021; Martins et al., 2004). In addition to verbal communication, nonverbal communication (e.g., mimicry and tacit behaviour) was viewed as a crucial factor for virtual team work (Schulze and Krumm, 2017; Stokols et al., 2008). Olson and Olson (2000) found that reading conversation partners' appearance and behaviour helps establish common ground.

Various technological factors influence virtual teams, e.g., type of technological equipment used, technical training and support and data security issues (Gaudes et al., 2007; Kilcullen et al., 2021; Stokols et al., 2008). The technology[2] used should fit the activities to be performed and enable goal achievement (e.g., networking) (Maynard et al., 2017; Zhang et al., 2018). Lack of co-presence was found to constrain virtual teams because when looking around the same environment, one may receive inputs from surroundings that can serve as conversation starters and supporters (Olson and Olson, 2000).

Team members' personal characteristics (e.g., expectations, experiences and attitudes) are important to work effectively in virtual teams (Gaudes et al., 2007; Schulze and Krumm, 2017). In particular, members' perceived ease of use and usefulness of technology, and members' technology readiness proved to be important for virtual teams (Stokols et al., 2008; Zhang et al., 2018). The literature found that a virtual team's size, team member diversity and team members' familiarity with each other influence virtual teams' efficacy (Gaudes et al., 2007).

Team leadership is another influential factor for virtual teams, as motivated and passionate leaders can impact team dynamics positively (Gaudes et al., 2007). Berente and Howison (2019) identified team leaders as being responsible for motivating people to follow desired

[1] In this article, virtual communication refers to the use of digital information and communication technology to communicate between two or more people across temporal/spatial boundaries.

[2] Technology is viewed as digital tools, platforms and software used for virtual communication.

norms to work in virtual teams and lead by example. The literature emphasises the establishment of common social norms and alignment of team members' expectations and argues that team leaders should ensure good timing so that meetings do not become unnecessarily long (Berente and Howison, 2019; Kilcullen et al., 2021).

3. Conceptual framework: input, process and output factors

In this study, I applied the IPO framework to structure factors that participants mentioned as influencing networking efficacy during VCs. The IPO framework (Hackman and Morris, 1975) has been used dominantly as a conceptual lens through which to study virtual team efficacy. In particular, the framework has been applied in studies that review existing research on virtual teams (e.g., Gaudes et al., 2007; Martins et al., 2004). Overall, the IPO framework indicates how input factors influence various team processes, which influence team outputs (Hackman and Morris, 1975). An explanation of IPO factors and exemplar categories for each are provided below and in Fig. 1.

Input factors refer to team's initial conditions and resources before members start to interact (Gaudes et al., 2007; Maynard et al., 2017), e.g., members' characteristics, team composition, material and human resources (e.g., technological support, skills, knowledge, and leadership), structural context and external setting (Martins et al., 2004; Pinsonneault and Caya, 2005; Powell et al., 2004). Given these examples, I assume that similar input factors play a role in networking during VCs.

Process factors include processes happening within a team when its members interact with each other while working together (Powell et al., 2004). Exemplar categories include member participation, communication, and coordination (Martins et al., 2004; Powell et al., 2004). Further, planning, goal setting, timing, monitoring, conflict management and other group dynamics are defined as team processes (Martins et al., 2004; Pinsonneault and Caya, 2005). Team processes also can be viewed as interactions that transform input factors into outputs (Gaudes et al., 2007). In this study, process factors refer to interactions that occur during VCs to facilitate networking. Nevertheless, I expect process factor categories to resemble the aforementioned examples.

Output factors are teamwork outcomes (Gaudes et al., 2007), which often include team performance, team members' satisfaction with outcomes (Powell et al., 2004) and behavioural outcomes (Martins et al., 2004). Instead of team efficacy, this study uses networking efficacy during VCs as an output factor.

4. Methodology

Twenty-one semi-structured interviews and one follow-up interview with one of the participants were conducted between May and August 2022 to examine VC organisers' and attendees' experiences with VCs. By applying convenience sampling, most participants were recruited with initial key informants' help within my university and 'The Future of Meetings' (TFOM) community (see https://tfom.org). Through snowball sampling, prior participants referred the remaining participants. Inclusion criteria were that participants had to be researchers who had attended and/or organised a virtual international conference. To maximize variation in perspectives, participants were selected from myriad scientific disciplines, academic career stages and geographical regions, i.e., those employed at not only European institutions, but also more remote ones (e.g., New Zealand). An equal gender distribution was sought, resulting in a final sample of 11 male and 10 female participants (see Supplementary Table A1 for a detailed description of participants' demographics). Data collection was stopped when no new factors were raised in the interviews and thus data saturation was reached (Glaser and Strauss, 2017).

Interviews were conducted in person (N = 8) or virtually via Zoom (N = 13) in English (N = 12), German (N = 6) or Swiss German (N = 3), and lasted between 30 min and 1.5 h. The interviews followed a guide (Supplementary Information B) and comprised three parts. The first focused on VCs in general. The second asked participants to elaborate on specific VCs, and the tools and formats used therein. In the final part, participants' demographics were assessed. All participants provided written voluntary and informed consent to participate in the study. Twenty interviews were recorded and subsequently transcribed verbatim. Notes were taken for one interview because the participant did not want to be recorded. In the interviews, participants talked about one to three different virtual international academic conferences they had attended/organized, which varied in size and type, thus achieving diversity not only across participants but also in conferences.

Based on a grounded theory approach (Strauss and Corbin, 1998), the interview transcripts were analysed in two steps. During the first open-coding cycle, a subset of three transcripts was coded line-by-line with pen and paper by paraphrasing sentences, thereby deriving codes close to the data inductively. Subsequently, the interviews were analysed using generated codes and new codes derived from the data in the qualitative data analysis software MAXQDA. During the second cycle, attention was paid to similarities and patterns among codes, resulting in centralisation of codes around two broad themes: i) VCs' advantages and disadvantages, and ii) factors facilitating or constraining networking during VCs.

In a second step, all interviews were re-analysed to structure identified factors based on the IPO framework. As this study focused on networking during VCs, networking efficacy was set as the sole output factor. Subsequently, the factors that participants mentioned as facilitating or constraining networking during VCs were categorised as input or process factors. These were subdivided into different categories based on those identified in the literature (e.g., Martins et al., 2004; Pinsonneault and Caya, 2005) and my interpretation of the data (Fig. 2).

5. Results

The participants provided a broad range of experiences with VCs and mixed feelings towards them, including positive experiences and good outcomes of VCs. Nevertheless, participants also mentioned negative experiences, describing VCs as inferior, not comparable and less effective in terms of benefits and outputs compared to in-person conferences. Participants felt that myriad approaches to VCs were available, and that their experiences depended on the organisation, attendees, organisers and the conference's purpose. Overall, participants agreed that VCs have both advantages and disadvantages (see Supplementary Tables C1-2 for a list of advantages and disadvantages mentioned in the interviews).

Participants described several outcomes from VCs, e.g., exchanging and sharing (unpublished) scientific results, generating new research ideas, making oneself and one's research known in the community and seeking future employment opportunities. These factors could be classified as output factors too, but are not discussed further in this article. Instead, networking efficacy is used as the output factor to answer the research questions focusing on networking during VCs. Networking is, as participants stated, key to building collaborations, new projects and career opportunities. Participants viewed networking as meeting people, making connections and personal contacts, and building friendships and relationships:

> 'Some conferences […] had very good after hours and social interaction. […] That has actually been very successful in building those friendships and connections. So, I do feel when done properly, VCs can develop those relationships pretty much at the same level of fidelity as being in person' (ID12).[3]

> 'We designed specific social events to try and facilitate informal engagements through things like networking, bingo and trivia' (ID10).

[3] All quotes were corrected for grammar, syntax and clarity. German quotes were translated into English and are marked with an *.

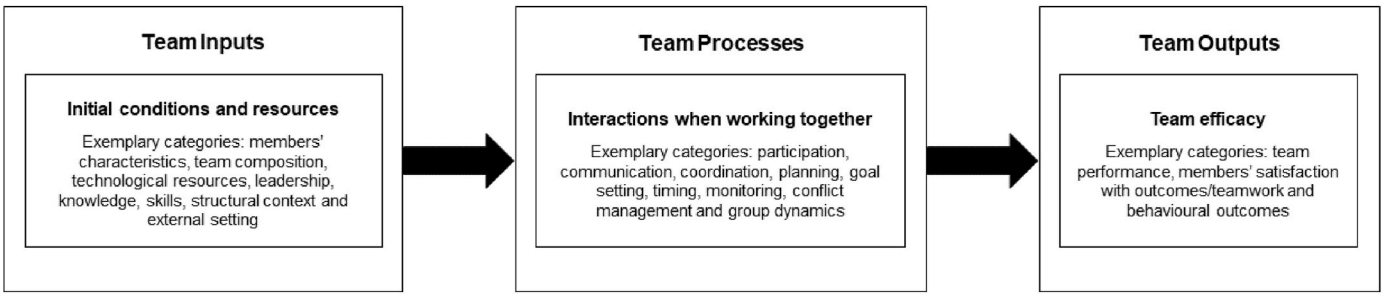

Fig. 1. Overview of the input-process-output framework with exemplar categories from the virtual teams literature (Martins et al., 2004; Pinsonneault and Caya, 2005; Powell et al., 2004).

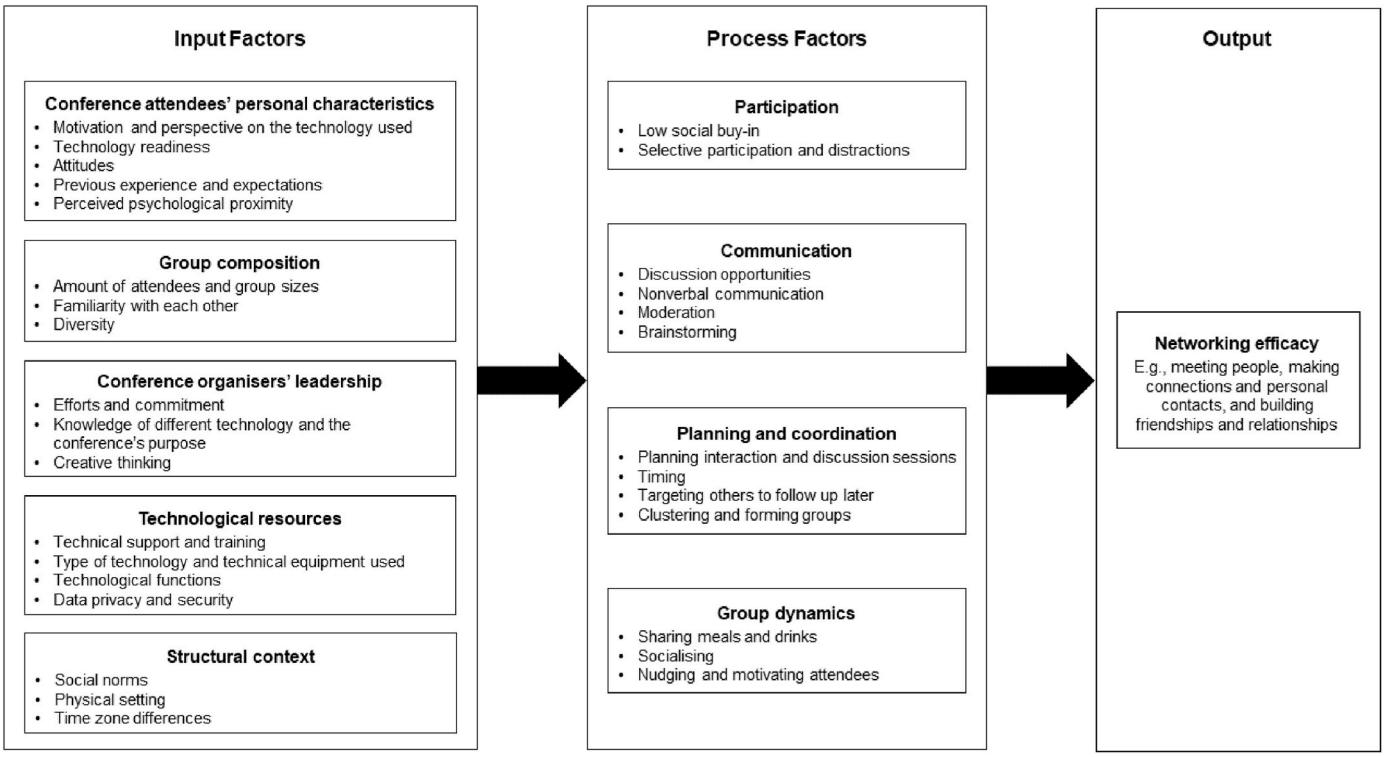

Fig. 2. Input and process factors that participants mentioned as facilitating or constraining networking during VCs.

The IPO framework was used to structure the factors that participants mentioned as facilitating or constraining networking during VCs. The factors and overarching categories (Fig. 2) are discussed in more detail below.

5.1. Input factors

5.1.1. Conference attendees' personal characteristics

Participants believed that perceptions of VCs depend on attendees' *motivation*, enthusiasm and willingness to use conference technology, and their motivation to interact with each other. Participants said it is the responsibility of the individual attendee to use the technology provided during the conference and interact with others. Many participants also referred to attendees' *perspective on the technology used*, including perceived ease of use and the technology's usefulness. Some felt that the technical inhibition threshold should be as low as possible, so that the adoption barrier for the technology can be kept to a minimum:

> 'You have to remove all the friction – as much friction as possible – because online, it is harder to motivate yourself to interact' (ID04).

Participants perceived attendees' *technology readiness* as influencing networking efficacy during VCs. This was viewed as attendees' familiarity and comfort with technology, and their experience and knowledge about technology. Many stated that technical hurdles should be minimised to save time spent on figuring out how technology works:

> 'People will only join the platforms they already know […] because if people do not know [the platform], they lose time with it and maybe are not so active' (ID05).

> 'If they do not have an affinity for technology, then [the entire conference] suffers a bit in my eyes. Because people also leave [the conference] again when they realise that it [the technology] does not work' (ID11*).

Another factor participants mentioned was attendees' *attitudes* towards VCs in general, and the technology used therein. Some participants indicated that the perception of networking during VCs is dependent on attendees' general mindset towards VCs and 'the way that people treat online conferences – how seriously they take them' (ID10):

> 'I am finding that people are thinking of [VCs] as being a bit of a second-class thing. […] They have been totally given a bad reputation by bad conferencing and the wrong attitude' (ID14).

This reluctance to embrace virtual communication may lead to reduced uptake of virtual networking sessions. Participants noted the influence of *previous experience* attending VCs, as conclusions about perceived networking efficacy during VCs are based on attendees' experiences. Participants felt that 'people need to have more of those [positive VC] experiences and find out more about the different ways technology can help interact' (ID10). Simultaneously, participants mentioned attendees' *expectations* as influential factors, and that networking efficacy during VCs depends on attendees' expectations of the VC and their perceptions of what networking at conferences should look like:

> 'I guess my expectation is not that high for online conferences. I guess I am not expecting to use them for networking' (ID19).

> 'You have to be aware that it [VC] is not the same as a classic in-person conference, where you are in one place for several days with the same people' (ID03*).

Also influencing networking efficacy during VCs is attendees' *perceived psychological proximity*, i.e., the feeling of being connected, close and in the same place even though attendees are in different locations. Participants felt that an immersive feeling was missing in VCs and that they often felt alone and disconnected:

> 'I think with a screen and a speaker, my body just realises too firmly that the [other] people are not here. My body realises on a psychological or stimulus level with other people that I am physically alone' (ID11*).

Other participants mentioned that virtual reality technology can bridge physical isolation and provide a more immersive experience:

> 'You really have the feeling that you are somewhere else. That is the feeling these [virtual reality] glasses really convey. […] We had a conference meeting on a little island with a little campfire in the middle, and I really had the feeling that I was there' (ID13*).

5.1.2. Group composition

Other stated input factors were categorised under group composition. Participants felt that the networking efficacy during VCs was influenced by the *amount of attendees and group sizes*:

> 'At large conferences, this [social session] was of course not the case. That is, the opportunity for small talk has not arisen at all' (ID07*).

Participants also viewed attendees' *familiarity with each other* as important requirements for social interaction:

> 'I feel like with all of these things [nonverbal communication], if you know someone, it will go well later since you got the necessary sensitivity for it' (ID11*).

Participants also mentioned attendees' *diversity* and referred to the opportunity to meet more people who, due to travel barriers, would not have been able to attend the conference had it not been held in a virtual format:

> 'So even though in-person events might be better for networking for the people who were there, they are infinitely worse for networking for the people who cannot make it' (ID04).

5.1.3. Conference organisers' leadership

Participants frequently pointed to the importance of good leadership among conference organisers, as they associated experiences with VCs with conference organisers' *efforts and commitment*:

> 'It [the experience with networking] really depends on the organisers and on setting the mood for [networking] to happen' (ID17).

Participants believed that conference organisers should think thoroughly about how best to design the conference, connect attendees and take enough time to plan the conference. They also viewed conference organisers' *knowledge of different technology and the conference's purpose* as important factors. Participants felt that conference organisers should know which platforms are effective for which purposes, thereby using suitable technology:

> 'We did a lot of research into different platforms and how effective they would be, and we chose a platform based on our [conference] goals' (ID10).

Another participant added that conference organisers should know and take into account attendees' needs. Someone else elaborated on this:

> 'Most people are still not really thinking much about how the online world and in-person world are different and that they, therefore, have a successful online event if they do things differently. […] They [online and in-person conferences] can fill different niches, so you do not have to try and create an in-person event in an online setting' (ID04).

Participants believed that conference organisers should bring in *creative thinking* to embrace the virtual format – not just copy and paste in-person formats:

> '[Conference organisers] have to find a way to attract the attention of people' (ID02).

5.1.4. Technological resources

The most frequently mentioned input factors referred to technological resources, including the importance of having technical support *and training* before and during a VC. Several participants reported having technical support staff or co-hosts so that technical issues could be mitigated as much as possible. Others noted that rehearsals with speakers before a session are essential to minimise time lost resolving technical issues during a session:

> 'It does not work if […] people are not instructed on how to deal with the virtual format and are thrown in a deep end and then quickly shut off after the presentation' (ID03*).

Participants mentioned that networking efficacy during VCs depends on the *type of technology and technical equipment used*:

> 'How good those networking experiences were depended on which kind of software people were using.' (ID01).

Diverse virtual tools and platforms were mentioned as suitable to facilitate networking. Participants noted the advantage of using different technology simultaneously, with multiple communication channels, but not overloading attendees. Several participants considered it important to have technology that allows for asynchronous and synchronous interactions.

Participants said it is important to include various *technological functions* to facilitate networking during VCs. They most frequently referred to virtual venues and the spatial autonomy they provide. The ability to move around a space/map, see who is where, freely choose which room to enter and walk up to people to interact with them were viewed as particularly valuable:

> 'Using Gather.town (see https://www.gather.town) is actually quite amazing in the sense that you do feel like you are just walking around and meeting people. […] I think walking around makes people feel like they are at a conference' (ID16).

Participants also stated having a list of attendees and their contact details made networking easier, providing opportunities to contact other attendees via email or social media. Other functions mentioned were matchmaking software, virtual whiteboards, chat threads and social events (e.g., online games).

Participants believed that *data privacy and security* influences

networking efficacy during VCs and worried about outsiders listening in, being unwillingly recorded or taken out of context:

> 'There is always the possibility that things will be recorded. […] I would not make any form of joke virtually, which I might sometimes do in person, as everything can potentially be recorded, and you always have to think that things can then also be taken out of a context. […] You do not have confidentiality virtually' (ID01*).

5.1.5. Structural context

The final group of input factors refers to structural context. Participants mentioned *social norms*' influence, comprising general perceived norms about virtual and in-person conferences. Some participants noted that senior researchers in particular generally wish to maintain face-to-face interactions as a norm. Other participants appreciated the increasing normalisation of virtual communication. One participant suggested that new virtual social norms can enhance VCs:

> 'The advantage [of in-person conferences] is that people are used to all of these little social norms, because they have been attending them for years. Whereas at good online events, no one is used to those social norms' (ID04).

Another factor category is the *physical setting*. Participants said networking is easier at in-person conferences because you are there for several days, stranded or stuck in a conference venue/city far from everything else:

> 'In-person events have this massive advantage that you are all stranded in a city together. So, when the conference finishes, […] people just go to dinner together and continue to form bonds and links' (ID04).

Others mentioned the importance of inputs from the surrounding environment and a feeling of a space/place:

> 'I do not think that this [virtually sharing a drink together] works because you are still in your work environment. […] And I am not as relaxed there as I would be if I was sitting somewhere on a beach and talking to people in a completely relaxed environment – in a new environment that also evokes different sensory impressions' (ID13*).

Furthermore, participants perceived *time zone differences* as influencing networking efficacy during VCs, as it was difficult for them to get in contact with people in other time zones.

5.2. Process factors

5.2.1. Participation

Participants mentioned several processes that occur during VCs and influence networking efficacy. One process deemed a prerequisite to facilitate networking during VCs was attendees' participation. Participants viewed this as a constraining factor, with *low social buy-in* for networking opportunities and little adoption of VCs' interactive discussion elements:

> 'If you organise a [social session], and no one shows up, it is really hard to get the informal interaction going' (ID10).

Similarly, participants experienced *selective participation and distractions* during VCs. Participants reported attending only sessions of interest or several VCs in the same week. Furthermore, attendees were distracted by incoming emails, colleagues stopping by the office, other important working tasks and/or family obligations:

> 'During the coffee breaks you do something else. You answer emails, you see a student or there is a department meeting. […] You tend to use the networking moments to do the rest of what you have to do' (ID02).

5.2.2. Communication

Facilitating networking during VCs was associated strongly with communication, e.g., exchange and interaction among attendees. Participants considered it important for attendees to have *discussion opportunities*, including one-on-one conversations, small group discussions, small talks, side chats, live discussions and chatting platforms. While some participants reported positive experiences – e.g., organic social discussions – during VCs, others found it difficult or impossible to have casual, unstructured conversations to get to know others. There was also disagreement regarding random, spontaneous and serendipitous chats, as some believed that discussions during VCs always had to be structured, organised and scheduled, whereas others stated that they, indeed, had unplanned chance encounters:

> 'Something that is missing [in VCs] is the possibility of [approaching] someone and starting a useful conversation. [In in-person conferences], at the end of the talk, you go out for a coffee, and you see someone who is not busy. […] You can just approach them and have a chat without having to make it official and set up a time for a proper chat' (ID17).

> 'For example, [when] using Gather.town, people kind of just bumped into each other and introduced themselves, and then found something in common, and went off and did stuff together' (ID16).

Participants found networking during VCs constrained by a lack of *nonverbal communication*, e.g., reading facial expressions, establishing direct eye contact, recognising body language and gestures, and receiving feedback from and assessing other people:

> 'I feel like – biologically speaking – you need a lot more inputs than just a picture of a person' (ID11*).

> 'There are many aspects of communication that cannot be reproduced by a video. How a person moves, how enthusiastic a person seems in relation to a certain topic, whether someone is already tired in a conversation, […] or having the feeling of now is just the right moment' (ID01*).

Participants also believed that *moderation* is key to leading discussions and giving voices to different attendees:

> 'We also encouraged people, if their breakout discussions had more than five or six people, to just nominate someone to be the moderator and to use the [raise] hand feature to allow everyone to feel that they have a way to be heard' (ID04).

Another factor that participants mentioned was *brainstorming*. While some participants felt that it was difficult to replace collaborative work in front of a blackboard, others used platforms with virtual post-it notes to brainstorm.

5.2.3. Planning and coordination

Participants mentioned planning and coordinating VCs to facilitate networking, in which they viewed specifically *planning interaction and discussion sessions* as particularly important:

> 'You need to organise the networking because otherwise, it will not take place. You need to give time for discussion' (ID15).

> 'The programme must be ready. You cannot just say stay on Zoom, and nothing [happens]. It must be prepared' (ID05).

Participants also felt that conference sessions' *timing* was important, stating that different time zones should be taken into account, breaks should be scheduled and sessions should not run too long:

> 'And because [the VC] was not so strictly timed due to the small group size, it was possible to have better conversations after the talks' (ID07*).

Participants talked about specifically *targeting others to follow up later*

in a separate conversation:

> 'You listen to a talk, and you just want to discuss afterwards with the person. I just send them an email, and we organise a meeting either on Zoom or in person […], just to have a chat' (ID15).

Participants also viewed *clustering and forming groups* as an important factor for facilitating networking during conferences, in that they could form groups spontaneously and split up into smaller groups. While some participants felt that this was difficult or impossible to do at VCs, others reported that it, indeed, was possible when using a suitable platform.

5.2.4. Group dynamics

Another set of process factors was related to group dynamics. Participants mentioned the importance of *sharing meals and drinks* to facilitate networking, as 'there is something nice about being able to sit down with someone or with a group of people and share a meal' (ID21). Participants viewed this as a constraining factor with VCs, as it is not (yet) possible to sit around tables and have a drink or meal together:

> 'When you go out for dinner together later in the evening and talk to each other for three to four hours, it is just a different exchange than just chatting again for 15 minutes on Zoom. […] I feel if you are eating something together, it is a more casual atmosphere and you do not have to talk all the time' (ID20*).

Participants indicated that *socialising* facilitates networking and getting to know one another, e.g., playing online games together, having conversations in virtual reality, attending virtual happy hours and chatting during virtual coffee breaks:

> 'Social activity where you have a purpose, where you are doing something, is a lot easier than [when you are] just meant to talk to people' (ID14).

Participants also associated networking facilitation during VCs with conference organisers *nudging and motivating attendees* to engage, interact and discuss matter with each other:

> 'One key thing that I think made our conference more successful is that we as organisers were constantly nudging people and reaffirming the kind of social norms we wanted' (ID04).

6. Discussion

With the IPO framework's help, this study structured the factors that participants mentioned as facilitating or constraining networking during VCs. Thus, for the first time, a systematic analysis has been conducted on the factors that influence networking efficacy during VCs. Due to the IPO framework's clear structure and the inclusion of diverse participants and VCs from different scientific fields and countries, this study paints a more holistic picture than existing reports on the experience of organising VCs in a particular scientific field. The results obtained provide valuable insights for the shift from academic air travel to more sustainable and inclusive research exchange by illustrating that best practice examples of effective virtual conferences facilitating networking exist.

Most of the input and process factors that participants mentioned as influencing networking efficacy during VCs were consistent with factors that extant literature found influenced virtual team efficacy (e.g., Martins et al., 2004; Pinsonneault and Caya, 2005; Powell et al., 2004). However, some factors are likely to be unique to networking efficacy, such as the importance of having spatial autonomy, forming groups and clustering, sharing meals and drinks, and targeting others to follow up later in separate conversations. The factor of perceived psychological proximity also seems to be particularly relevant in the context of conferences, as they often last longer than team meetings.

The results suggest that sessions with a small number of attendees and with attendees who already know each other are easier to hold virtually, which is supported by a previous interview study (van de Glind and Gomez-Baggethun, 2022). This indicates that it is more difficult to initiate a network virtually than to maintain an existing one, which previous surveys have found (Köhler et al., 2022; Wenger, 2022). Therefore, it may be crucial for new attendees to gain access to an existing network by being invited and mentored by an established researcher during an existing networks' networking session. Thereby, networking could be more focused and planned, and help to build and maintain a network with the people whom one has met by – as participants mentioned – building on it through separate virtual one-on-one meetings, which are easy to set up and can reduce one's carbon footprint as they do not require travel.

Consistent with previous experience reports on VCs (Günther et al., 2021; Lowell et al., 2022; Reshef et al., 2020), the results demonstrated that conference organisers should provide technical training, rehearsals and support, and proper technical equipment for VCs. Zhang et al. (2018) found in their survey that barriers to participating in virtual networking sessions should be as low as possible by using technology that is easy to use and learn. The equipment should be designed specifically for networking and provide features that include spatial autonomy and enable people to connect and follow up. Participants viewed it as particularly important to be able to see who is where and freely choose which room to enter or which group to talk to, so they can meet other attendees. Furthermore, virtual brainstorming software and online social activities were mentioned as vital networking tools.

Previous observations with organising a VC suggested specifically incorporating discussion sessions to focus on communication and interaction among attendees (Porwol et al., 2022). The present study confirmed this finding, as participants perceived it as particularly relevant to provide time for discussions, thereby specifically planning VCs' networking parts. However, participants stated, in line with interviews conducted by Strengers (2015), that the lack of sensory cues and nonverbal communication made it difficult to get a sense of other people, thereby constraining networking during VCs. To mitigate this, participants and other conference organisers (Roos et al., 2020) suggested that VC organisers can motivate and encourage attendees to engage actively and slowly establish new virtual social norms.

6.1. Limitations and future research

The study was limited by interviewing participants from mostly two communities (my university and the TFOM community) and a limited number of scientific disciplines (e.g., few participants from the social sciences). Participants were primarily employed in European, North American and Australian institutions, i.e., Global South representation was lacking. Furthermore, professors are overrepresented in the sample as recruiting early career conference organisers proved to be difficult. The generalizability of the results to other regions and scientific disciplines is therefore limited. This should be considered when interpreting the results, as a different context could introduce new factors that were not addressed in this study. Furthermore, the VCs discussed by participants mostly took place during the COVID-19 pandemic – a period associated with negative emotions (e.g., fear and anxiety), which may have influenced participants' experiences with VCs during this time.

Notably, the IPO framework presented in this study (Fig. 2) was based on interview responses and, thus, participants' perceptions of factors that influence networking efficacy during VCs. The input and process factors presented in this study could be confirmed or complemented by future studies that examine some of these factors through laboratory or field observations. The IPO framework used in this study is limited in that it assumes a clear causality between input, process and output, when in reality these factors are not always sequential in time and may not be easily distinguishable. It is also worth noting that input and process factors mentioned in this study not only influence networking efficacy during VCs, but may also influence hybrid conferences, which could be further investigated in future studies. In addition,

future research could analyse networking efficacy during in-person conferences to compare with this study's results.

Future research should continue to evaluate community sentiment towards VCs over time, as conference formats and structures, as well as attendees' attitudes towards them, may change. Research should also be conducted in other scientific fields and geographic regions and include a more diverse set of stakeholders involved in conferences. Specific attention should be payed to incorporate the perspectives and needs of minorities and vulnerable groups, such as attendees with disabilities and budget or visa constraints. Studies can evaluate new innovative conference tools and platforms that facilitate networking during VCs, and systematically analyse their benefits and limitations based on this study's categorisation. Continuously improving virtual networking can contribute to the shift from academic air travel to more sustainable and inclusive research exchange.

6.2. Practical implications

Conference organisers' important role, i.e., investing effort and motivation to think creatively about the most appropriate conference technology and structure, was highlighted in this and previous studies (Lowell et al., 2022; Moss et al., 2021). As also stated by Neubauer et al. (2021), VC organisers should organise conferences based on their goals. Considering that the interviews indicated that conference organisers should have sufficient knowledge about what technology and formats they can use to achieve their goals, resources that provide various options on tools for virtual communication can serve as support (e.g., see https://thefutureofmeetings.wordpress.com/tools/).

To facilitate networking, conference organisers should plan sessions that facilitate interactivity and discussions, using tools and platforms specifically designed for such interactions, e.g., matchmaking platforms and social virtual environments (Le et al., 2020; Song et al., 2021). Furthermore, nonverbal communication can facilitate networking (Stokols et al., 2008), so technology that best enables this should be used. For example, Maloney et al. (2020) found that virtual reality technology can stimulate nonverbal communication that can be perceived similarly to face-to-face communication, and can be enhanced in the future by improved hand and facial tracking.

In the coming years, conference organisers should continue to try out different structures, formats and tools for networking during VCs, driven by the needs of their communities. By evaluating these innovations continuously, new best practices can be found that lead to positive experiences with future VCs. Through this testing and development, more experience with networking during VCs will be gained so that conference organisers and attendees can become familiar with structures and technology that work best and thus shift from academic air travel to more sustainable and inclusive research exchange.

With current relaxations of COVID-19 travel restrictions, researchers are eager to meet in person again, and air travel started bouncing back to pre-pandemic levels (IATA, 2022). Thus, various forms of hybrid conferences emerged that allow for a combination of in-person and virtual participation, thereby reducing a conference's carbon footprint by changing requirements for academic air travel while maintaining a fair amount of physical contact and interaction. Assuming that the results of this study also apply to the virtual components of hybrid conferences, this article provides timely insights for post-pandemic conference organisation. Improving virtual networking during hybrid conferences will be an important step towards more sustainable conferencing. However, it remains to be tested and explored in future studies and hybrid conferences how best to combine virtual and in-person attendees to facilitate networking between them.

7. Conclusion

This article contributes to research and practice by structuring the factors that VC organisers and attendees perceive as facilitating or constraining networking during VCs. The findings revealed that conference organisers play a central role in specifically planning sessions that facilitate networking and that best practice examples for effective networking during VCs exist. By considering the results of this and future studies alongside best practice reports, it will be possible to significantly improve virtual networking, currently perceived as the biggest drawback of VCs. Thus, this study can be taken as a starting point to show how academic air travel can be reduced by substituting air travel to in-person conferences with effective virtual conferences. Hopefully, more virtual conferences will be held in the near future, following the best practices of effective virtual networking and thus making a substantial contribution to the shift from academic air travel to more sustainable and inclusive research exchange.

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Ethics approval

The study design was reviewed and approved by the ETH Zurich Ethics Commission (EK-2022-N-51).

CRediT authorship contribution statement

Ariane Wenger: Conceptualization, study conception and design, data collection, Formal analysis, analysis and interpretation of results, and manuscript preparation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.137577.

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