Use of aviation by climate change researchers: structural influences, personal attitudes, and information provision

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Abstract

Aviation is a fast-growing sector, releasing more carbon dioxide per passenger kilometre than other transport modes. For climate change researchers, work-related travel – including for conferences and fieldwork – is a major carbon-emitting activity. At the same time, many argue that climate scientists have an important role in curbing their own aviation emissions to align their practices with their assertions in relation to emissions reduction. We examine the tensions between competing professional demands in relation to flying; measure levels of flying by climate and non-climate researchers; assess influences on choices and attitudes; and consider how information provision and structural changes might enable changes in practice. Study 1 entails a large, international survey of flying undertaken by climate change (including sustainability and environmental science) researchers and those from other disciplines (N=1,408). Study 2 tests effects of varying information provision on researchers' behavioural intentions and policy support to reduce flying (N=362). Unexpectedly, we find climate change researchers – particularly professors – fly more than other researchers, but are also more likely to have taken steps to reduce or offset their flying. Providing information about the impacts of aviation increases behavioural intentions and support for institutional policies to reduce flying, particularly amongst more pro-environmental respondents. However, while attitudinal factors (e.g., personal norm) predict willingness to reduce flying, structural/social factors (e.g., family commitments, location) are more important in predicting actual flying behaviour. Recent initiatives to develop a low-carbon and more inclusive research culture within climate science and the broader research community thus need to be supported by broader policies and technologies to encourage and enable low-carbon and avoided travel.

Keywords: aviation, climate change, researchers, information

Highlights

- Large, international survey and experimental study of academic travel
- Climate change researchers, especially professors, fly more than other researchers
- Information provision increases intentions and policy support for reduced flying
- Structural/social factors are stronger predictors of flying than attitudinal factors
- Knowledge alone is insufficient to change workplace travel choices

1 Introduction

1.1 Background

By 2050, aviation is projected to account for around one-quarter of global CO_2 emissions (Owen et al. 2010), releasing more carbon dioxide per passenger kilometre than other transport modes (European Environment Agency, 2014). Mitigating this will require behavioural as well as technological change (European Environment Agency, 2014). For academics (like many professionals), work-related travel is a major carbon-emitting activity (Rosen 2017, Spinellis and Louridas 2013). An atmospheric science institute study found that over 90% of researchers' carbon emissions were caused by air travel (Stohl 2008; cf. Ciers et al. 2019). Recently, there have been growing calls both within and outside the research community for scientists, and climate change researchers in particular, to do more to curb their flying (Nature 2015, Jackson 2017, Williams 2019) not least to ensure that vital messages about the need for emissions reduction are not undermined by perceived hypocrisy or inconsistency with researchers' activities. One recent paper, for example, noted the paradox of sustainable transport researchers not questioning their own travel practices; and more generally that academia turns a blind eye to the environmental impact of its 'hypermobility', which may be seen as a barrier to rapid action to reduce carbon footprints (Caset et al. 2018, p.64; cf Grémillet 2008).

Whether one accepts the normative argument that climate change researchers *should* lead by example (Nordhagen et al. 2014, Le Quéré et al. 2015; Higham and Font, 2020), evidence indicates that climate scientists who reduce their carbon footprint are seen as more credible and more likely to inspire behaviour change and policy support amongst the public than those who do not reduce their emissions (Attari et al., 2016, 2019). Conversely, people often justify their flying with reference to the lack of action taken to reduce flying by high-profile figures, as a sign that the problem is not serious enough to warrant action (King et al. 2009). Several universities and research centres have developed low-carbon travel policies, favouring less carbon-intensive travel modes or using virtual alternatives (e.g., videoconferencing) (Hasan et al. 2018). However, while a number of studies have now addressed various facets of climate impact of research activities, there is as yet little research into the practices and motivations of academics (including climate change researchers) themselves in relation to flying, nor the opportunities to influence these to be more sustainable.

1.2 What influences flying practices?

While there is a general acknowledgment that travel is environmentally damaging, public understanding of the relative impact of flying on the climate, compared to other activities, seems to be lower (Gössling et al. 2006, Shaw et al. 2006) although some recent evidence indicates this may be changing (Capstick et al., 2019b). Providing realistic information about the damage caused by aviation can increase concern (Becken 2007), though this may only weakly influence flying behaviour (King et al. 2009, Barr et al. 2011, Hares et al. 2010, Randles and Mander 2009). The structural drivers of international travel (e.g., norms, status, professional pressures, disposable income) may prevent concern manifesting in behaviour change (Hares et al. 2010, Randles and Mander 2009, Cohen and Higham 2011, Wang and Song 2010, Gössling et al. 2019, Kantenbacher et al., 2018). This is not least because mobility by air is deeply entrenched in Western societies, with many flights perceived to be 'necessary' (Higham et al. 2014, Gössling et al. 2019). Even many who 'slow-travel' (i.e., use non-aviation modes) for leisure appear to do so mainly for cost rather than environmental reasons (Dickinson et al. 2010). Past research has suggested that reducing flying is one of the less popular actions to tackle climate change (Whitmarsh et al. 2011), with even environmentally-conscious people flying (Barr et al. 2011), and suppressing their climate change concern when in tourist spaces (Cohen et al. 2013).

Less research has explored the drivers of workplace (including academic) aviation, but this too points to a lack of alignment between attitudes and action. A study that found no relationship between environmental concern and travel behaviours also found low awareness of the relative contribution of air travel to climate change (Lassen 2010). Barriers to reducing work-related air travel include rejection of personal responsibility for professional emissions, and social norms and practices surrounding the use of air travel for work purposes, including what has been termed 'conference culture' (Lassen 2010, Øksnevad and Vaeng 2013, Høyer and Naess 2001). Studies show that decision-making around academic travel rarely includes consideration of alternative modes, with aviation typically the default choice (Øksnevad and Vaeng 2013). Globally expanding social and professional networks may portray flying not only as desirable but may also create a sense of obligation to travel in order to establish and maintain contacts (Urry 2002, 2003) – indeed many researchers consider it 'essential' for a successful academic career (Hopkins et al, 2019). Nevertheless, although there is some evidence that academic flying increases with seniority (Ciers et al. 2019), there is little objective evidence that it is in fact beneficial to one's career (Wynes et al. 2019), or does create culturally diverse networks (Derudder & Liu, 2015).

Social and family relationships can both enable and constrain academic travel: some may use academic trips as an opportunity to visit friends or take a family vacation; while others with caring responsibilities may avoid international travel or use the quickest mode available (usually flying; Hopkins et al., 2019; Storme et al. 2013). Parenthood therefore has the potential to influence academic mobility and modal choice, and to contribute to gender inequity in academic mobility, particularly in more remote regions (Cohen et al., 2019). Academic mobility patterns are also a product of international migration (Hoffman, 2008), which itself is promoted by many scientific institutions wanting to foster global collaboration and attract leading academics from overseas (Fontes et al., 2012). Indeed, it is important to explore travel perceptions and practices across different geographies and disciplines, since some regions such as Australia and the Pacific offer few if any alternatives to flying within or between countries, and there may be different institutional and cultural norms surrounding travel across academic fields and locations (Higham et al., 2019). To date, however, studies of academic travel have tended to focus on a single or small number of institutions. Our study, then, makes an important contribution to this field by undertaking the first large-scale international, cross-disciplinary study of academic travel – with a particular focus on comparing those who study climate change with those who do not.

1.3 Flying by climate change academics

Flying practices of academics matter for the pursuit of a low-carbon research culture, and the credibility of public-facing communication (Attari et al., 2016, 2019). Hence, it is important to understand academics' perceptions, specifically, the extent to which they fly and why, in order to identify opportunities to influence both individual decision-making and wider academic practice. Furthermore, by focussing on the carbon-relevant actions of *climate change researchers*, experts on climate change, we are able to better understand the role of knowledge in relation to relevant behaviour – are those who know the most about climate change more likely to take action to address it? While studies show information provision and knowledge may influence behaviour, the effect is usually small or absent (Whitmarsh, 2011; though see Shi et al., 2016). Other factors – such as social or institutional norms (e.g., conference culture), and structural factors (e.g., remote location, limited funding) are likely to be more important in explaining action, particularly travel (Higham et al., 2019; Whittle et al., 2019; Whitmarsh, 2009). This broader view, taking into account structural and cultural factors, helps explain why, despite growing awareness of the climate crisis and availability of virtual alternatives, academic travel appears not to have declined (Hopkins et al., 2019; Storme et al, 2017). Indeed, the only study that we have found to have compared environmental researchers (specifically, conservationists) with other researchers (economists and medics) from primarily the US and UK, found conservationists had only slightly smaller personal carbon footprints (including taking fewer personal flights) than other researchers, but took no fewer work flights than medics (Balmford et al. 2017). Here, we report on two studies – including a global survey of academics and an experimental study – that build on this nascent evidence base and seek to offer timely insights for reducing the carbon footprint of academic travel.

2 Study 1: How much do climate change researchers fly, and why?

2.1 Study 1: Aim

Study 1 comprised a large, international, online survey of university-based researchers from a range of disciplines, including climate change researchers and those from other disciplines. We aimed to investigate how much flying (for work and personally) those studying climate change (who may be considered 'climate change experts') undertake, relative to other researchers (or types of 'experts'), and what influences these travel practices. For work travel, we focussed on non-commuting travel as this accounts for the largest share of researchers' carbon footprint (Stohl, 2008).

2.2 Measures & Materials

Given the paucity of research in this area, most items used in the survey instrument were new and developed on the basis of previous transport studies (see above); although several background variables applied established, validated measures (e.g., Steentjes et al., 2017). The survey was piloted with a sample of UK climate change researchers.

2.2.1 Travel behaviours

Respondents were first asked for frequency of flying and other travel modes for work purposes and leisure:

- How often do you use an aeroplane to reach an academic conference or meeting, to conduct fieldwork or for other work purposes? (If you have only recently started work or study, please indicate expected frequency for the future.): (a) Within your country, (b) Outside your country but within your continent, (c) Beyond your continent. Response options were: Never (1), Less than once a year (2), Once a year (3), Twice a year (4), Three times a year (5), Four times a year (6), Five or more times a year (7).

- How often do you use non-aviation means of transport (e.g. rail, private car, bus, ferry) to reach an academic conference or meeting, to conduct fieldwork, or for other work purposes? (If you have only recently started work or study, please indicate expected frequency for the future.) (a) Outside your country but within your continent, (b) Beyond your continent. Response options were as above.
- How often do you use an aeroplane for personal/leisure purposes (e.g. holidays, visits to family)? (a) Within your country, (b) Outside your country but within your continent, (c) Beyond your continent. Response options were as above.
- How often do you use non-aviation means of transport (e.g. rail, private car, bus, ferry) for personal/leisure purposes (e.g. holidays, visits to family)? (a) Outside your country but within your continent, (b) Beyond your continent. Response options were as above.

2.2.2 Attitudes to work-related travel and alternatives

Respondents were then asked to rate attitude statements about work travel:

- To what extent do you agree or disagree with the following statements related to travel for the purposes of work? Attitude statements are shown in Figures 2 and 7. Responses options were: Strongly agree (5), Tend to agree (4), Neither agree nor disagree (3), Tend to disagree (2), Strongly disagree (1).
- Which of the following, if any, would be most influential in encouraging you to use non-aviation means of transport for work purposes? Please select up to three answers. Response options were those shown in Figure 6.
- Overall, do you feel that virtual options, such as Skype and video-conferencing, are better or worse than meetings and conferences where participants are physically present? Response options were: Much worse (1), Slightly worse (2), About the same (3), Slightly better (4), Much better (5).

2.2.3 Use of offsetting and alternatives to travel

Respondents were asked about their use of carbon offsetting[1] and steps to reduce work-related flying:

[1] We did not ask whether respondents' employers bought offsets for their flights, as we focus here on personal action.

- How often, if at all, do you buy carbon offsets for the flights you've taken for work? Response options were: Always (5), Most of the time (4), About half the time (3), Occasionally (2), Never (1) or Not applicable (e.g., I don't fly) (9).
- In the past 12 months, have you deliberately chosen to use a non-aviation means of travel for work because of the carbon footprint of the travel? Response options were: Yes (1), No (0)
- In the past 12 months, have you deliberately chosen not to travel to a work event because of the carbon footprint of the travel? Response options were: Yes (1), No (0).

2.2.4 Willingness to switch from aeroplane to other modes

Respondents were then presented with four scenarios in which they were asked about their willingness to switch from aviation to non-aviation modes. There were 16 cost scenarios ($100, $200, $300, $400, $500, $600, $700, $800, $900, $1,000, $1,100, $1,200, $1,300, $1,400, $1,500, $1,600) and 16 time scenarios (1hour through 16 hours) and participants were randomly presented with two of each in two separate questions. Examples of each are shown here:

- Consider a journey that you wish to take for work that would cost US$100 (100 US dollars) to travel by aeroplane. What is the highest total cost (in US DOLLARS) you would be willing to incur in order to take this journey by non-aviation means of transport instead, assuming a similar period of time spent travelling?
- Consider a journey that you wish to take for work that would take ONE hour by aeroplane. What is the longest total period of time in HOURS you would be willing to spend using a non-aviation means of transport (e.g. train, car) instead, in order to undertake this journey?

2.2.5 Knowledge and background measures

Finally, respondents answered questions about their knowledge and attitudes to climate change, and a range of job-related and demographic factors (see Table 1, below):

- How would you describe your knowledge of climate change? Response options were: I am an expert on climate change (5), I know a lot about climate change (4), I know a fair amount about climate change (3), I know a little about climate change (2), I don't know anything about climate change (1)
- How worried, if at all, are you about climate change? Response options were: Extremely worried (5), Very worried (4), Somewhat worried (3), Not very worried (2), Not at all worried (1)
- Does your work involve researching or teaching on climate change or sustainability? Response options were: Yes - this is a major part of my work (3), Yes - this is a minor part of my work (2), No (1). For analysis, we compared the first and last of these groups, labelling them ‘experts’ (17%; N=219) and ‘non-experts’ (65%; N=832).

2.3 Study 1: Participants

We stratified-sampled 30 universities from the QS University Rankings: ten were selected from the top third, ten from the middle third, and ten from the bottom third of the Rankings. We then contacted academics in sampled disciplines (biology, chemistry, economics, sociology, history, music, and environmental sciences) whose email addresses (N=ca.10,000) were available on their institutional website. Consistent with the Dillman method of survey research (Hoddinott and Bass 1986), which seeks to ensure a good response rate for surveys, we emailed these prospective participants (week commencing 14th August 2017) to alert them that we were conducting the survey and that, unless they preferred not to participate, the survey link would be emailed to them the following week. Several participants requested to be removed from our email contact list after the initial email. The remaining participants were emailed the link between Monday 21st and Thursday 24th August, 2017 in several batches. We supplemented this sample with email recruitment to the 'Future Earth' environmental science network. Participants were encouraged to respond by entry into a prize draw for £200. The final sample achieved was 1,408 (representing a 14% response rate). Of these, 43% were female; there was a spread of age and career levels, albeit it somewhat fewer older respondents (Table 1). Participants were resident in many countries, particularly the UK, Netherlands, and Australia[2].

Table 1. Demographic and professional characteristics of Study 1 sample

		%
Gender	Male	55.2
	Female	43.1
	Other/missing	0.2
Age	18-24	1.6
	25-34	34.1
	35-44	29.9
	45-54	18.2
	55-64	11.4
	65+	4.8
Country	UK	26.2
	Netherlands	35.2
	Australia	10.9
	USA	5.7
	Italy	3.0
	Canada	2.1
	Germany	1.9
	South Africa	1.6
	Ghana	1.1
	India	1.0
	Spain	1.0
	Other (48 further countries, including Belgium, France, Turkey, Switzerland, New Zealand, China, Brazil, Nigeria, Peru Sweden)	10.3
Have children	No	47.7
	Yes (all)	52.3
	Yes – aged under 5	14.1
	Yes – aged 5-10	12.5
	Yes – aged 11-17	11.5
	Yes – aged 18 or over	16.3
Job role	Taught under-/post-graduate	3.0
	PhD student	17.2
	Research Associate/Fellow	23.9

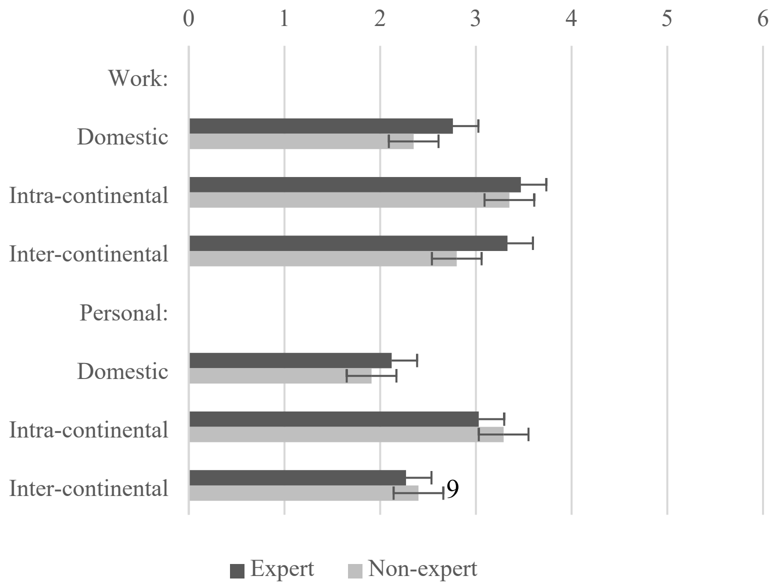
[2] The survey was conducted in English which may partly explain higher rates of completion amongst Anglophone countries and the Netherlands, which has the highest rate of English-speakers outside the Anglosphere (https://www.ef.co.uk/epi/). It is unlikely that issue concern explains differing response rates: countries with higher response rates were no more concerned about climate change than other countries (e.g., 22% in UK, 15% in NL and 17% in Australia were 'extremely worried' versus 46% in Germany, 10% in S. Africa, 21% in Ghana, and 25% in India.)

	Assistant/Associate Professor	29.1
	Professor	18.3
	Other/missing	8.5
Discipline	Earth sciences	5.4
	Biology	16.5
	Engineering	2.6
	Chemistry	6.0
	Economics	7.5
	Sociology	11.4
	Environmental science	7.8
	History	10.1
	Music	2.6
	Other	30.2
Climate change knowledge	I don't know anything about climate change	0.9
	I know a little about climate change	24.2
	I know a fair amount about climate change	46.6
	I know a lot about climate change	22.4
	I am an expert on climate change	6.0
Work on climate change / sustainability	No	64.6
	Yes – minor part	18.4
	Yes – major part	17.0
Conduct fieldwork	No	51.0
	Yes	49.0

2.4 Study 1: Results

We compared responses from those for whom climate change or sustainability is a major part of their work ('experts'; N=219), versus those for whom it is not ('non-experts'; N=830). While the median amount of flights taken was similar for both experts and non-experts, overall we found significantly higher levels of flying amongst climate change experts (see Figure 1 and caption). Based on median response categories shown in Figure 1, our data indicate that experts typically took around five flights per year (one domestic, two intra-continental, and two inter-continental); for non-experts the equivalent figure was four flights per year (no domestic, two intra-continental, and two inter-continental). Both groups took similar numbers of personal flights, the median for both groups being around three per year (zero domestic, two intra-continental and one inter-continental).

Figure 1. Frequency of climate change experts' and non-experts' work and personal flying per year. Frequency scale was: Never (0), Less than once a year (1), Once a year (2), Twice a year (3), Three times a year (4), Four times a year (5), and 5+ trips per year (6). (Work domestic and inter-continental flights significantly higher for experts than non-experts, p<.05). Error bars = +/1 1 SE.



We considered whether the nature of climate change research – with its more global focus – might result in more travel, for example to conduct fieldwork. Indeed, climate change and sustainability experts do appear to do significantly more fieldwork: 41.3% of non-experts versus 64.8% of climate change experts conduct fieldwork (X^2 (1, N=1,050)= 38.72, p<.001). However, this only partly explains the difference in flying frequency: international travel is still higher amongst the climate change experts, even controlling for fieldwork (main effect of expertise: F(1)=18.01, p<.001). When including expertise and fieldwork along with other possible predictors of flying in a linear regression analysis (Table 2), we see demographic variables and family commitments do not significantly predict level of flying. Levels of flying do rise with job seniority, and vary by location (European researchers are less likely to fly than those working elsewhere). Climate change expertise and conducting fieldwork remain significant positive predictors. One of the strongest predictors of work-related travel, however, is the amount of flying undertaken for leisure. This may indicate that both work and leisure flying are influenced by a common third factor, such as a more general inclination or habit to fly, over and above the other personal and structural variables we have measured. Levels of leisure flying may also itself be a function of income (Wang and Song 2010), although this was not directly measured.

Despite the amount of flying that is done by experts, they nevertheless do report higher levels of awareness and concern about the impact of aviation on climate change. Perceived personal responsibility for the impacts of travel, personal norms (perceived obligation to act) and pro-environmental self-identity are all also found to be at higher levels among experts than non-experts (Figure 2). Yet, despite an established literature showing that these factors predict many pro-environmental behaviours (Klöckner 2013), climate change knowledge and concern are non-significant or weak predictors of flying in our researcher sample (Table 2).

Figure 2. Climate change experts' and non-experts' beliefs about and attitudes to flying and climate change.
Response scale: 1= strongly disagree to 5 = strongly agree. All differences between groups are significant at p<.05. Error bars = +/- 1 SE.

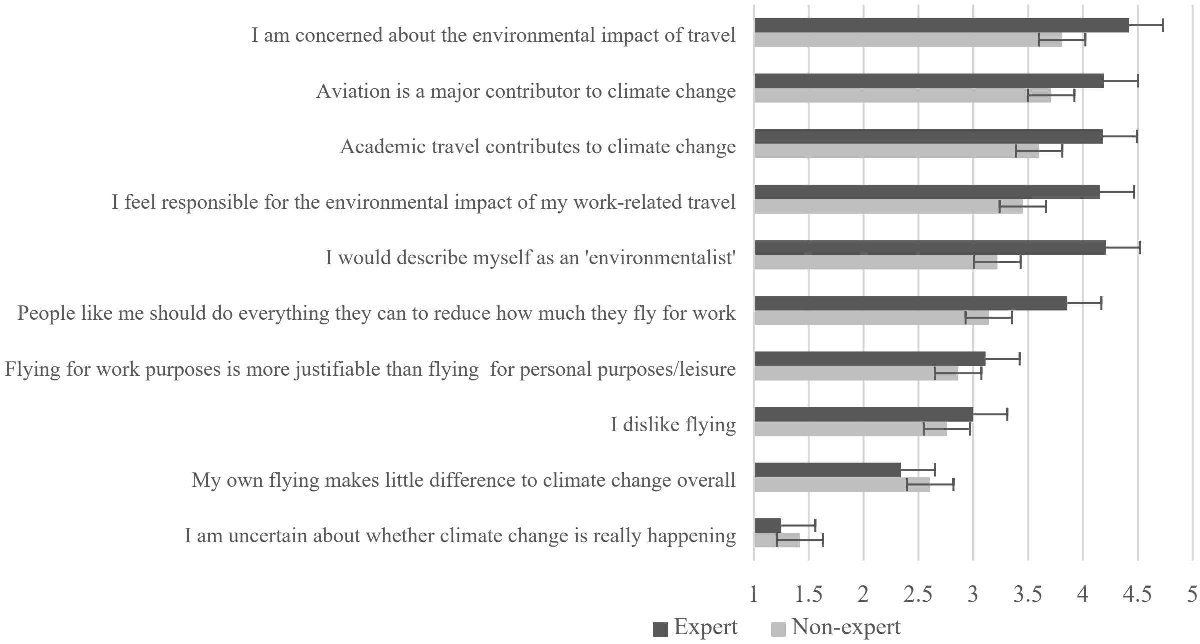


Table 2. Regression analysis of number of work-related flights undertaken. *Significant predictors in bold; R^2 =.27; N=1,408; CC = climate change*

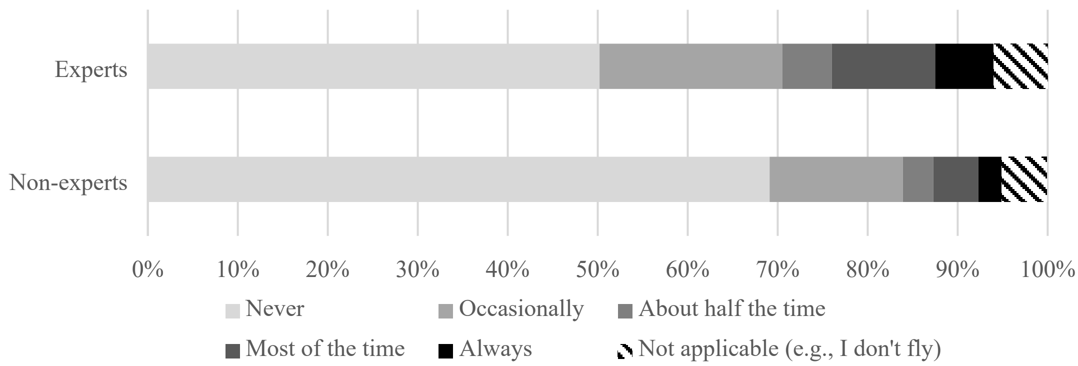
	Beta	**t**	**Sig.**
Gender (M=1, F=2)	-0.04	-1.51	0.13
Age	-0.03	-0.57	0.57
Children under 5	0.01	0.25	0.80
Children 5-10	0.03	0.99	0.32
Children 11-17	0.05	1.56	0.12
Children 18+	0.00	-0.10	0.92
Student	0.09	1.39	0.17
Researcher	**0.17**	**2.62**	**0.01**
Asst/Assoc Professor	**0.26**	**3.89**	**0.00**
Professor	**0.42**	**7.14**	**0.00**
UK	**-0.15**	**-3.58**	**0.00**
Mainland Europe	**-0.13**	**-3.05**	**0.00**
North America	-0.03	-0.81	0.42
Asia	0.04	1.29	0.20
Africa	0.00	-0.10	0.92
South America	-0.06	-1.90	0.06
Conduct fieldwork	**0.08**	**2.82**	**0.01**
CC major part of job	**0.09**	**2.35**	**0.02**
CC knowledge	**0.08**	**2.27**	**0.02**
CC worry	-0.02	-0.72	0.47
Total personal flights	**0.36**	**12.73**	**0.00**

Despite flying more for work, climate change experts are more likely to have offset their flights, used alternatives to travel, and avoided travel, for climate change reasons (Figure 3): 43.8% of experts offset flights at least occasionally versus 25.8% of non-experts; $X^2(5, N=1,032) = 33.63$, $p<.001$; 37.9% of experts have chosen non-aviation modes for work in last year due to carbon footprint, versus 16.5% of non-experts; $X^2(1, N=1,050) = 47.99$, $p<.001$; 29.2% of experts have chosen not to travel for work due to carbon footprint, versus 5% of non-experts ; $X^2(1, N=1,051) = 111.74$, $p<.001$.

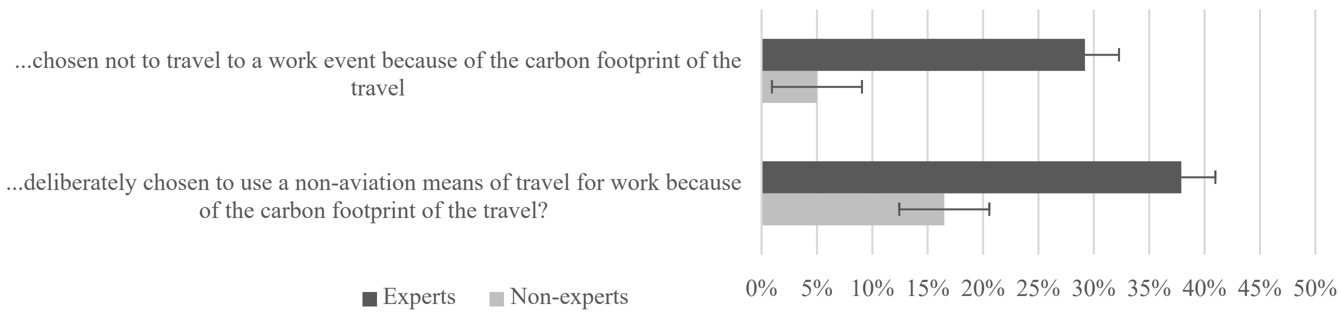
When asked the extent to which people were willing to incur additional time or financial cost to switch from flying to ground transportation (Figure 4) we find this is particularly pronounced for shorter and less expensive flights. There was a stated willingness to use non-aviation alternatives for journeys of up to four times the duration for shorter flights; this fell to only twice the duration for longer flights. In terms of financial cost, the equivalent ratios we observed were smaller overall: people were willing to spend up to 1.5 times the cost to switch to overland in the case of cheaper flights, but a ratio closer to 1:1 was observed for more expensive flights.

Figure 3. Use of carbon offsetting & alternatives to aviation by climate change experts and non-experts

(a) How often, if at all, do you buy carbon offsets for the flights you've taken for work?



(b) In the past 12 months, have you…



Comparing experts and non-experts, we see relatively little difference in their willingness to switch modes, although there is a greater willingness to pay more for non-aviation alternatives amongst experts. Flying tends to be seen as cheaper, faster and easier than alternatives; travel is perceived to help build networks and be enjoyable; while virtual options are seen as worse than face-to-face meetings/conferences (Figures 5-7). However, experts were significantly less negative about virtual options (e.g., videoconferencing) than were non-experts (Figure 5). When asked about measures to reduce academic flying (Figure 6), experts were also significantly more supportive of publishing staff travel emissions ($X^2(1,1050)=9.26, p<.01$), staff in similar circumstances reducing their flying ($X^2(1,1050)=9.50, p<.01$), a university/centre-wide policy to reduce staff travel emissions ($X^2(1,1050)=19.41, p<.001$), and more video-conferencing ($X^2(1,1050)=14.45, p<.001$); while non-experts were significantly more in favour of reducing the cost of non-aviation alternatives

($X^2(1,1050)=7.05, p<.01$). The reasons stated for flying, however, did not differ between experts and non-experts (Figure 7).

Figure 4. Relationship between willingness to pay (in time or money) for non-experts and experts. X- axis shows hypothetical amount presented (1 to 16hrs, or \$100 to £1600 dollars). Y-axis shows the multiple of that figure the respondent is willing to pay in time or money to avoid flying (travelling overland). Blue line represents mean and grey band 95% confidence interval.

(a) Non-experts (cost). (b) Experts (cost) (c) Non-experts (time) (d) Experts (time)

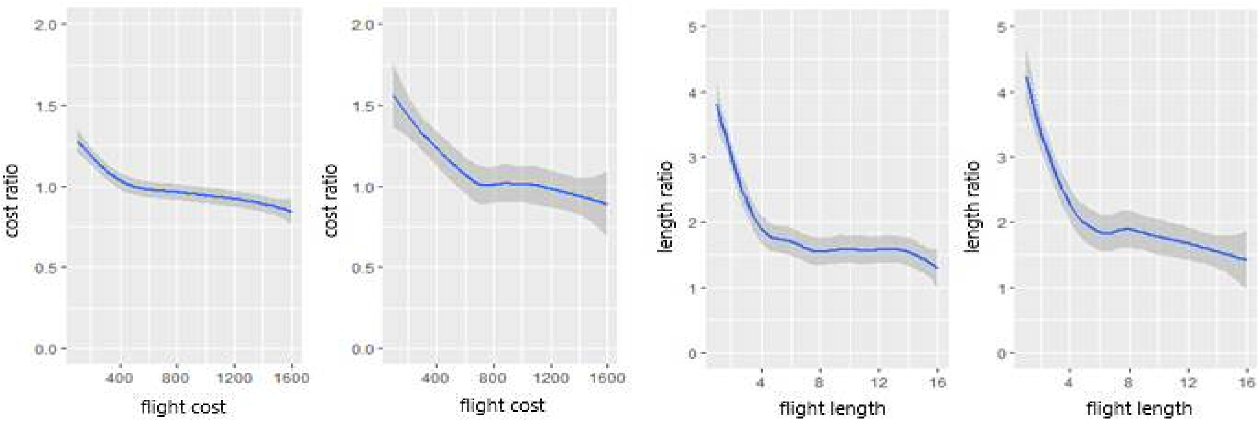


Figure 5. 'Overall, do you feel that virtual options, such as Skype and video-conferencing, are better or worse than meetings and conferences where participants are physically present?' Difference between experts and non-experts is significant: ($X^2(1,4)=19.37, p<.001$). Error bars = +/- SE.

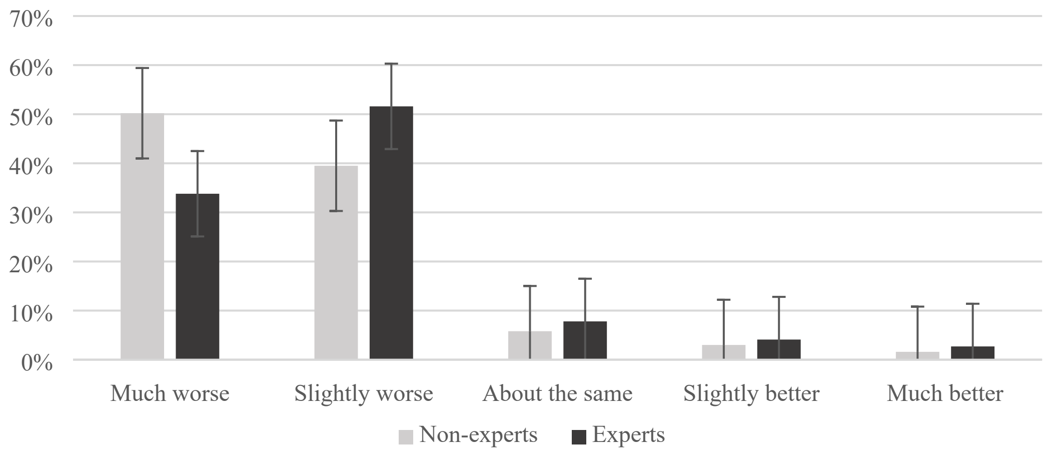


Figure 6. Measures that would encourage researchers to use non-aviation means of transport for work purposes. Respondents could choose up to three options; figure shown are a % of the sample.

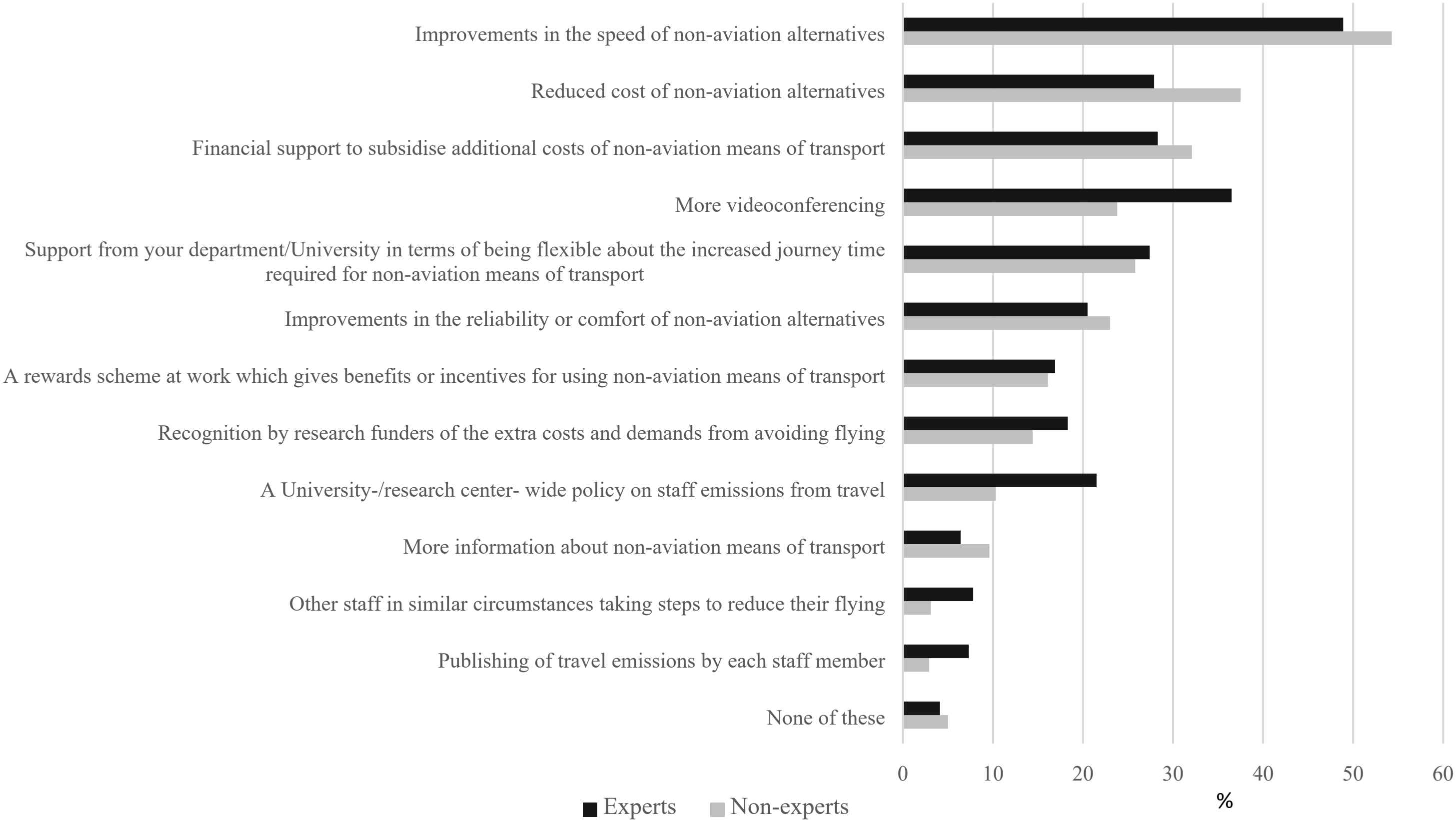
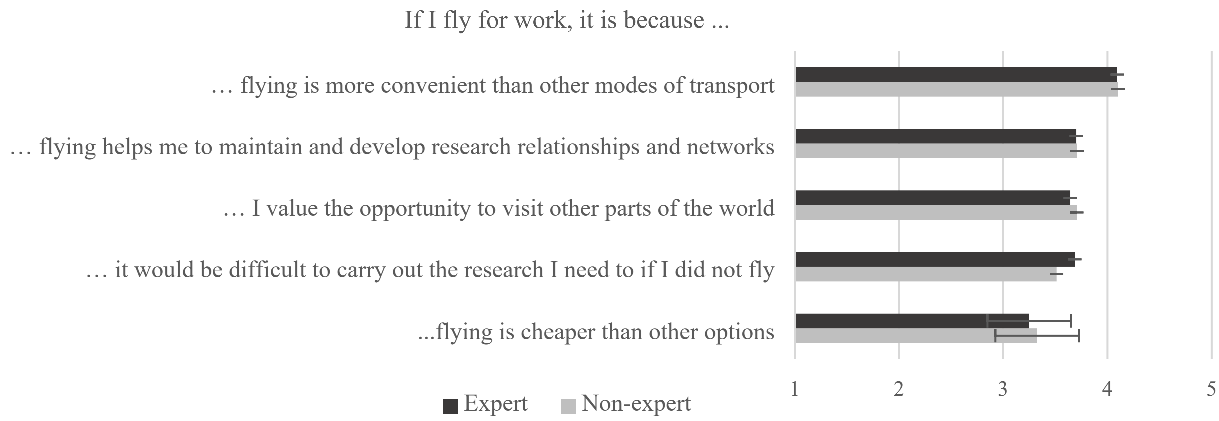


Figure 7. Reasons for flying for work (mean agreement). Responses options were: Strongly agree (5), Tend to agree (4), Neither agree nor disagree (3), Tend to disagree (2), Strongly disagree (1). Differences between experts and non-experts are non-significant.



3 Study 2: What difference does giving people information about climate change make?

3.1 Study 2: Aim and design

Study 1 suggested that climate change expertise was inversely associated with levels of professional travel; we also found that level of climate change concern did not predict amount of flying. However, this was a correlational design unable to entirely isolate the effect of knowledge and attitudes from potential confounding factors. In Study 2, we applied an experimental design across a sample of individuals (n=362 across three conditions) working in universities or research institutes and for whom research was a part of their role. We tested whether different types of information provision about the consequences of air travel affected willingness to reduce travel. While previous research suggests generic climate change knowledge may not straightforwardly predict behaviour, there is more likely to be a relationship where information provided is specific to the behaviour in question (Dahlstrand and Biel 1997) (i.e., information about flying). In addition, studies show information framed in different ways can appeal to different audiences, according to their values or beliefs (Whitmarsh and Corner 2017). Clear awareness of the consequences of one's choices is emphasised in several theoretical models as an important prerequisite for activating personal norms (obligation) to act (Klöckner 2013). Emphasis on the social justice aspects of environmentally-significant choices can prompt behavioural responses, however this has been shown to vary according to a person's values and worldview (Whitmarsh and Corner 2017). Thus, we compare the differential effects of provision of information about (a) the environmental impacts and (b) the social justice aspects of aviation, versus (c) control information, on researchers, while taking into consideration study participants' existing environmental values, climate change knowledge and political ideology. For the former experimental condition, we presented information about environmental impacts that emphasised the relatively higher CO_2 emissions of aviation per km than other modes; for the latter, we presented information about the disparity between the carbon emissions of the richest versus poorest, and made reference to the particular vulnerability of the poorest to the impacts of climate change.

Study 2 also afforded the opportunity to provide a deeper and more theoretically informed analysis of the predictors of willingness to reduce workplace travel and support workplace policies to achieve this. Specifically, we compared the relative efficacy of two theoretical models which are the most widely applied in environmental psychology: the Value-Belief-Norm (VBN; Stern, 2000) model and the Theory of Planned Behaviour (TPB; Ajzen, 1991). The former assumes pro-environmental action, such as cutting down flying, is a moral action, predicted by personal norm (i.e., sense of obligation to act), personal ascription of responsibility to act, and awareness of consequences from one's actions (in this case, that aviation is environmentally damaging). In contrast, the TPB assumes intentions are predicted by attitudes, social norms, and perceived behavioural control (PBC; i.e., the ability to act), with habit sometimes included as an additional variable (e.g., Murtagh et al., 2012). These two models have been tested in relation to a range of pro-environmental behaviours (e.g., Kaiser et al. 2005), but to our knowledge not yet in the context of professional flying. Directly comparing these models allows us to infer whether support for cutting down on flying is at heart morally motivated or subject to other influences.

3.2 Study 2: Measures & Materials

3.2.1 Travel behaviours

Measures were those used in Study 1.

3.2.2 Intentions and policy support

We had two dependent variables in the experiment:

- Intentions to reduce flying/carbon impact was measured with a two-item scale comprising the items 'I intend to reduce how much I fly for work in the future' and 'I intend to reduce the carbon impact of my work-related travel'. Responses were from strongly agree (7) to strongly disagree (1) with an option for 'not applicable (e.g., I don't fly), excluded from analysis; (α=.78).

- Institutional policy support was measured with a two-item scale comprising the items 'I would support a policy in my workplace to restrict the amount of flying employees do' and 'I would support a policy in my workplace to encourage people to fly less for work' with responses again on a seven-point agreement scale (α=.83).

3.2.3 Values, knowledge, and background variables

Aside from the experimental manipulation (below), we had two independent variables (climate change knowledge and environmental values) for the experiment. In addition, we tested the VBN and TPB, so included relevant variables from these models:

- *Climate change knowledge* was measured as in Study 1
- *Environmental values* was measured with a six-item version of the New Environmental Paradigm (NEP) scale comprising the items: 'When humans interfere with nature it often produces disastrous consequences', 'The balance of nature is strong enough to cope with the impacts of modern industrial nations' (reversed), 'The balance of nature is very delicate and easily upset', 'Humans are severely abusing the environment', 'The so-called "ecological crisis" facing humankind has been greatly exaggerated' (reversed) and 'If things continue on their present course, we will soon experience a major ecological catastrophe' with a seven-point agreement scale from strongly agree (7) to strongly disagree (1); the scale was found to be reliable, α=.83.
- *Personal norms* were measured with a four-item scale (α = 0.80) consisting of the items: "I feel obliged to travel less for work out of environmental concern", "I would be a better person if I reduced the amount I fly", "The environmental impact of the flights I take for work makes me feel guilty" and "I don't feel guilty when I fly even though there are other feasible transport alternatives available" (reverse-coded).
- *Ascription of responsibility* was measured with a two-item scale (α = 0.75) comprising: "People like me should do everything they can to reduce how much they fly for work" and "I feel responsible for the environmental impact of my work-related travel".
- *Awareness of consequences* was measured with a six-item scale (α = 0.70): "Aviation is a major contributor to climate change", "Academic travel contributes to climate change", "My own flying makes little difference to climate change overall", "Changes in individuals' behaviour make little difference to climate change overall", "I rarely consider the impact that my flying behaviour has on the environment" and "I do not give that much thought to my own carbon footprint".
- *Attitudes* were measured with three sub-scales, since the full battery of attitudinal items did not form a reliable scale; PCA analysis instead found a three-factor solution. First, emotional attitude, included only one item, namely "I dislike flying". Second, a career attitude (α = 0.70) scale consisted of two items: "I fly for work because it would limit my career progression if I flew less" and "If I fly for work, this is because flying helps me to maintain and develop research relationships and networks". Third, a rational attitude scale (α = 0.62) included the items "If I fly for work, it is because flying is the quickest way of

reaching a destination" and "If I fly for work, it is because flying is more convenient than other modes of transport". Additional attitudinal variables were included that capture specific 'compensatory beliefs' (Capstick et al., 2019a) about pro-environmental action: "Any flying I do for work is made up for by environmentally friendly behaviours in other aspects of my life" was called compensatory belief a and the item "Flying for work purposes is more justifiable than flying for personal purposes/leisure" was called compensatory belief b.

- *Social norms* comprised two elements: descriptive norm was measured with the item "Most of my colleagues fly for work"; while injunctive norm was measured with the item "If I fly for work, it is because I am expected to fly by my university/research project".
- *Perceived behavioural control* items did not form a reliable scale, so instead three sub-scales were generated: "If I fly for work, it is because flying is the only possible way of reaching my destination" and "It would be difficult to carry out the research I need to if I did not fly" were included as single items in the analysis and called work-related PBC a and work-related PBC b. The two remaining items ($\alpha = 0.69$) and were called private PBC: "My family commitments mean that I have to limit the amount of travel I do for work", "My family commitments mean that I need to fly rather than use other means of travel". Although both PBCs are perceived with regard to work-related flying, work-related PBC includes work factors facilitating or obstructing flying while private PBC includes certain private-sphere factors facilitating or obstructing flying[3].
- *Habit* was measured with the single item "If I fly for work, this is out of habit".

Background and job-related variables were included as in Study 1 (see Table 3). We also asked about *political ideology*: 'In politics, people sometimes talk of "left" and "right". Using the scale below, where would you place yourself on the political spectrum?' with an eleven-point scale from Left (0) to Right (10).

3.2.4 Experimental texts

Participants were allocated to read one of three pieces of text carefully and told they would be asked questions afterwards. The texts included some relatively technical information (in English), deemed appropriate given the educational and professional backgrounds of study participants.

(a) *Environmental impacts*: "The aviation industry is one of the fastest growing sectors in the world. In 2010 there were 1.9 billion flights a year globally; by 2015 this figure reached 3.6 billion. Business travel accounts for 41% of all purposes for air travel (NHTS, 2004). Academics and researchers are among these passengers, travelling frequently for conferences, project meetings and fieldwork. Air travel is responsible for significant quantities of carbon dioxide (CO_2), a major cause of climate change; by 2050 aviation is predicted to account for around a quarter of global CO_2 emissions (ICAO, 2016). Despite this, emissions from air travel are one of the few sectors that are not covered by international climate change agreements. Air travel typically emits more CO_2 per kilometer than other modes of transport such as trains, cars, coaches and ferries. Furthermore, research has shown that the

[3] Our pilot work and other studies (e.g., Hopkins et al., 2019) indicated family commitments were likely to be the most significant such private-sphere factors, although we acknowledge that other factors (e.g., health) could also be relevant.

high altitude emissions from air travel have 2-4 times more impact than equivalent emissions at surface level (IPCC, 2006). Technological advancements are unlikely to compensate for the negative environmental impacts of flying, with such a growing demand for air travel (OECD, 2008). It has been argued that one of the ways in which academics and researchers can help to limit their own emissions is by reducing their air miles, in particular by limiting their flying for work events (e.g., conferences; Rosen, 2017). In many cases, alternative modes of transport to flying, such as trains, can be used; or meetings can be attended virtually using video-conferencing, YouTube recordings or Skype."

(b) *Justice*: "The risks and impacts of climate change are not shared equally. Within and between countries, people who are already socially, economically, and politically marginalized are especially vulnerable to climate change (IPCC, 2014). Although the poorest people in the world are the ones who will suffer the most from the impacts of climate change, they've done the least to cause it. The world's richest 10% produce half the world's carbon emissions; by contrast, the poorest half of the world's population produce only a tenth of global emissions (Oxfam, 2015). Emissions from air travel reflect the uneven way in which climate change emissions are distributed in society. In particular, personal emissions from air travel are strongly associated with income in rich countries. In the UK, aviation emissions of the top 10% of earners are around six times the size of the lowest 10% of earners (JRF, 2015). Air travel is responsible for significant quantities of carbon dioxide (CO_2), a major cause of climate change. Many propose that those who are more responsible for causing climate change should do more to tackle it. It has been argued that one of the ways in which academics and researchers can help to limit their own emissions is by reducing their air miles, in particular by limiting their flying for work events (e.g., conferences; Rosen, 2017). In many cases, alternative modes of transport to flying, such as trains, can be used; or meetings can be attended virtually using video-conferencing, YouTube recordings or Skype."

(c) *Control*: Participants were given information of the same length as the experimental texts about how to change a car tire (adapted from Whitmarsh and Corner, 2017).

For each of the three conditions, three multiple-choice questions (with three options) were asked about the information to check information assimilation. A score was calculated for the total number of correct responses:

- *Environmental impacts*: 51.8% answered all three questions correctly; 34.5% answered two correctly; 8.6% answered one correctly, and 5% answered none correctly.
- *Equity condition*: 70.6% answered all three questions correctly; 23% answered two correctly, and 3.2% each scored one or zero.

Thus, most participants appear to have read the information quite carefully. ANOVA showed no significant differences in the responses to the flying intentions questions based on the number of correct responses elicited for the environmental impacts ($F(3,139)=1.06$, $p=.370$) or justice ($F(3,126)=.491$, $p=.689$) conditions; so all cases were retained for further analyses.

3.3 Study 2: Participants

Participants were recruited between November 2017 and January 2018 from an online participant panel (Prolific[4]), screened for individuals working in universities or research institutes and for whom research was a part of their role. This included both postgraduate researchers, postdoctoral researchers and academic staff from a range of countries and demographic backgrounds (see Supplementary Information). Participants were randomised to one of three conditions: Environmental impacts (N=126), Justice (N=114), or Control (N=122; text shown above).

3.4 Study 2: Results

3.4.1 Predictors of work-related travel

First, we replicated the analysis from Study 1 to examine the predictors of work-related travel, and again found that climate change researchers fly more than other researchers. Those with children, who conduct fieldwork, and take more personal flights, also fly more for work (Table 3).

Table 3. Predictors of number of work-related flights taken in Study 2. Significant predictors in bold; R^2 = .33; N=375; cc = climate change

	Beta	t	Sig.
(Constant)		1.75	.08
Gender	-.088	-1.85	.07
Age	.071	1.34	.18
Have children	**.158**	**2.97**	**.00**
UK	-.011	-.09	.93
Rest of Europe	.063	.63	.53
N. America	-.084	-.80	.43
Seniority	.049	1.01	.31
Climate change knowledge	-.005	-.11	.92
Environmental values	.039	.82	.41
Conduct fieldwork	**.110**	**2.36**	**.02**
CC major part of job	**.129**	**2.54**	**.01**
No. personal flights	**.432**	**9.33**	**.00**

3.4.2 Comparing theoretical models for reduced aviation intentions and policy support

Next, we compared the two theoretical models – VBN and extended TPB – in predicting behavioural intentions to reduce flying and support for relevant policies. Regression analyses (Table 4) using VBN variables show only personal norm and ascription of responsibility are significant predictors for intentions ($p < .05$). In other words, people who have a stronger personal norm to reduce work-related flying and travel carbon impact, i.e. who feel morally obliged to fly less and reduce their travel carbon impact, have a stronger intention to reduce work-related flying and to support workplace policies to reduce flying. As for ascription of responsibility, the more internally the responsibility for negative impacts of work-related flying and travel carbon impact is ascribed, the stronger the intention is to fly less for work and reduce work-related travel

[4] Prolific (https://www.prolific.co/) is an online participant panel, widely used in academic studies and similar to MTurk but with more research-naïve respondents (Peer et al., 2017). Studies are advertised to potential participants (matching screening criteria) who have already joined the platform. Panel composition is international and diverse, although there is a higher proportion of members from the UK and US and from younger age groups (18-40 years). Participants are paid for participation.

carbon impact as well as to support workplace policies to reduce flying. Neither ecological worldview nor awareness of consequences are significant predictors for intention to reduce work-related flying. However, for support for workplace policies to reduce flying, awareness of consequences is a significant (though relatively weak) positive predictor. That is, understanding and accepting the environmental impact of flying (including academic and one's own work-related travel) increases support for workplace policies to address this.

Regression analyses for intentions to reduce flying using extended TPB variables (Table 5) show six of the predictors, namely, emotional attitude, work-related PBC, private PBC, compensatory belief variables, and habit have a significant influence. The more positive the emotional attitude (i.e., enjoying flying), the weaker the intention to reduce work-related flying. The weaker someone's *work-related* PBC over flying for work (i.e., they feel they cannot carry out their research without flying), the weaker their intention to reduce work-related flying. On the other hand, having a weak *private* PBC predicts intentions to reduce flying, meaning that family commitments force people to fly or in general travel less for work. Compensatory beliefs also predict intentions: the more convinced a person is that they can make up for work-related flying with other environmentally-friendly behaviours and the more they think that flying for work is more justifiable than for private matters, the stronger their intention to reduce work-related flying. This is perhaps due to a drive to present oneself as consistent across pro-environmental behaviours. Also counter-intuitively, the influence of habit on the intention to reduce work-related flying and travel carbon impact is positive. Among these significant predictors, work-related PBC has the biggest effect size. Lastly, rational attitude, career attitude, and social norms do not have a significant effect on intentions.

Table 4. Regression analysis on intentions and policy support of VBN variables

	Behaviour intention			**Policy support**		
	SE B	ß	p	SE B	ß	p
Constant	*0.31*	-	*0.03*	*0.37*	-	*0.37*
Ecological worldview (NEP)	0.06	0.00	0.99	0.07	0.05	0.25
Personal norm	**0.06**	**0.41**	**0.00**	**0.07**	**0.34**	**0.00**
Ascription of responsibility	**0.05**	**0.41**	**0.00**	**0.07**	**0.29**	**0.00**
Awareness of consequences	0.07	0.01	0.92	**0.09**	**0.14**	**0.01**
	Note. R^2 = .76			Note. R^2 = .71		

Table 5. Regression analysis on intentions and policy support of extended TPB variables

	Behaviour intention			**Policy support**		
	SE B	ß	p	SE B	ß	p
Constant	*0.58*	-	*0.00*	*0.64*		*0.00*
Rational attitude	0.07	0.00	0.99	0.08	-0.03	0.65
Emotional attitude	**0.04**	**-0.12**	**0.03**	**0.05**	**-0.15**	**0.01**
Career attitude	0.00	-0.01	0.87	0.00	0.11	0.06
Descriptive norm	0.05	0.04	0.49	0.05	0.11	0.05
Injunctive norm	0.05	0.07	0.24	0.05	0.07	0.24
Work-related PBC a	0.05	-0.02	0.75	0.06	0.02	0.74
Work-related PBC b	**0.04**	**-0.19**	**0.00**	**0.05**	**-0.19**	**0.00**
Private PBC	**0.05**	**0.12**	**0.02**	0.05	0.02	0.76
Compensatory beliefs a	**0.05**	**0.17**	**0.00**	0.05	0.06	0.29
Compensatory beliefs b	**0.05**	**0.14**	**0.01**	**0.05**	**0.14**	**0.01**
Habit	**0.05**	**0.14**	**0.01**	0.05	0.09	0.12
	Note. R^2 = .38			Note. R^2 = .33		

For policy support, only a subset of the significant predictors from above are significant, namely, emotional attitude, work-related PBC and compensatory beliefs. Again, emotional attitude has a negative effect, i.e. the more positive people's attitude towards flying for work, the less they support workplace policies to restrict flying. Likewise, people with a weaker PBC over work-related flying are less likely to support restrictive workplace policies,. The compensatory belief that flying for work is more justifiable then for private matters has the same effect as for intention: the stronger this belief, the stronger support for workplace policies restricting flying. Again, work-related PBC has the strongest effect on intention.

Comparing the two models, we see that substantially more variance is explained by the VBN (76% for intentions, and 71% for policy support) than the TPB (38% for intentions and 33% for policy support), despite the latter comprising more variables. VBN variables (personal norm and ascription of responsibility) are also stronger predictors than any TPB variables. This suggests that, while structural factors such as family commitments, exert some influence on willingness to reduce flying, internal, moral factors appear to be much more influential. It is also noteworthy that awareness of consequences (e.g., climate impacts of flying) exerted no effect on intentions and little on policy support, reinforcing Study 1 findings that climate change knowledge is not sufficient for behaviour change to reduce flying. We next examine whether enhancing this knowledge (through information) has any impact on intentions or policy support.

3.4.3 Impact of providing information on reduced aviation intentions and policy support

Finally, we explored the impact of providing information about the social and environmental impacts of aviation on travel-related behavioural intentions and policy support. Regression analysis (Table 6) shows a main effect of condition on intention to reduce flying: intentions are significantly higher for those having read either of the two experimental texts, than for those that did not. Furthermore, there is a main effect of NEP, with higher NEP scores predicting higher intentions to reduce flying. There is also a significant interaction between NEP score and justice-framed information and a marginally significant interaction with the environmental impacts framing. When climate change knowledge is used as a predictor instead of NEP, along with condition, there remains a significant main effect of condition and a main effect of climate change knowledge (those with more knowledge being more willing to reduce flying; Table 7). There is no significant interaction effect.

Examining the effect of condition and NEP on support for institutional policies to reduce flying (Table 8), there is again a main effect of condition (both experimental texts lead to more policy support than control text; and a main effect of NEP (higher NEP score is associated with more policy support). There is no significant interaction effect. Using climate change knowledge as an independent variable, condition remains significant as before, and so is climate change knowledge, while the interaction is only marginally significant (Table 9).

Looking across these analyses, we can see that most variance is explained in behavioural intentions and policy support by NEP; climate change knowledge also positively predicts both dependent variables, and political ideology predicts policy support. Experimental condition is also a positive predictor: giving people information about the environmental or social impacts of aviation (including academic flying) increases behavioural intentions and support for institutional policies to reduce flying. Some interaction effects were also found: the effect on policy support of giving those who know about climate change additional information about the impacts of flying is greater than for those with less extant knowledge; while those with higher NEP scores given more information about climate change impacts were particularly likely to intend to reduce their flying.

Table 6. Regression analysis of behavioural intentions to reduce flying, with information and environmental values (NEP) as predictors (Study 2)

Model (R^2)	DV: Behavioural intentions	Beta	t	Sig.
1 (.056***)	(Constant)		25.516	.000
	Condition - env impacts	**.257**	**4.356**	**.000**
	Condition - justice	**.203**	**3.443**	**.001**
2 (.121***)	(Constant)		2.951	.003
	Condition - env impacts	**.280**	**4.901**	**.000**
	Condition - justice	**.227**	**3.964**	**.000**
	NEP	**.257**	**5.166**	**.000**
3 (.139*)	(Constant)		3.446	.001
	Condition - env impacts	-.191	-.714	.476
	Condition - justice	.060	.601	.548
	NEP	**.190**	**3.052**	**.002**
	NEP x env condition	.479	1.802	.072
	NEP x justice condition	**.188**	**1.987**	**.048**

Table 7. Regression analysis of behavioural intentions to reduce flying, with information and climate change knowledge as predictors (Study 2)

Model (R^2)	DV: Behavioural intentions	Beta	t	Sig.
1 (.056***)	(Constant)		25.516	.000
	Condition - env impacts	**.257**	**4.356**	**.000**
	Condition - justice	**.203**	**3.443**	**.001**
2 (.076**)	(Constant)		6.906	.000
	Condition - env impacts	**.255**	**4.353**	**.000**
	Condition - justice	**.197**	**3.363**	**.001**
	CC knowledge	**.144**	**2.824**	**.005**
3 (.077)	(Constant)		4.512	.000
	Condition - env impacts	.227	.854	.394
	Condition - justice	.055	.212	.832
	CC knowledge	.115	1.318	.188
	CC knowledge x env condition	.029	.107	.915
	CC knowledge x justice condition	.149	.564	.573

Table 8. Regression analysis of policy support to reduce flying, with information and environmental values (NEP) as predictors (Study 2)

Model (R^2)	DV: policy support	Beta	t	Sig.
1 (.058***)	(Constant)		27.225	.000
	Condition - env impacts	**.272**	**4.771**	**.000**
	Condition - justice	**.187**	**3.277**	**.001**
2 (.156***)	(Constant)		2.287	.023
	Condition - env impacts	**.292**	**5.395**	**.000**
	Condition - justice	**.209**	**3.852**	**.000**

	NEP	**.313**	**6.666**	**.000**
3 (.161)	(Constant)		2.348	.019
	Condition - env impacts	.070	.272	.786
	Condition - justice	.114	1.212	.226
	NEP	**.283**	**4.803**	**.000**
	NEP x env condition	.227	.884	.377
	NEP x justice condition	.109	1.210	.227

Table 9. Regression analysis of policy support to reduce flying, with information and climate change knowledge as predictors (Study 2)

Model (R^2)	DV: Policy support	Beta	t	Sig.
1 (.058***)	(Constant)		27.225	.000
	Condition - env impacts	**.272**	**4.771**	**.000**
	Condition - justice	**.187**	**3.277**	**.001**
2 (.063*)	(Constant)		7.990	.000
	Condition - env impacts	**.272**	**4.792**	**.000**
	Condition - justice	**.182**	**3.208**	**.001**
	CC knowledge	**.111**	**2.265**	**.024**
3 (.067)	(Constant)		6.436	.000
	Condition - env impacts	-.133	-.519	.604
	Condition - justice	-.234	-.923	.356
	CC knowledge	-.019	-.225	.822
	CC knowledge x env condition	.420	1.624	.105
	CC knowledge x justice condition	.437	1.691	.092

4 Discussion and Conclusions

4.1 Summary

Flying is one of the most carbon-emitting actions that individuals can take, in a personal or professional capacity. Some argue that climate change researchers have a *heightened* responsibility to curb their aviation emissions to align their practices with their assertions in relation to emissions reduction. Here, we presented the first large-scale, global study of climate change and sustainability researchers, as well as a follow-up experimental study, exploring how much they fly, why, and how this might be reduced. In an international online survey of researchers, Study 1 found significantly higher levels of flying amongst climate change researchers than researchers from other disciplines. This was only partly explained by the greater amount of fieldwork undertaken by this group; the amount of flying is also predicted by level of climate change expertise, job seniority, location, and the amount of flying undertaken for leisure. Despite the greater amount of flying that is done by experts, they report higher levels of awareness and concern about the impact of aviation on climate change. They are also more likely to have offset their flights, used alternatives to travel, and avoided travel, for climate change reasons. While there was relatively little difference between climate change and other researchers in their willingness to switch travel modes, climate change researchers showed greater willingness to pay more for non-aviation alternatives and more support for institutional policies to reduce flying than non-experts. In general, flying was seen as cheaper, faster and easier than alternatives; travel is perceived to help build networks and be enjoyable; while virtual options are seen as worse than face-to-face meetings/conferences (albeit less so amongst climate researchers).

In Study 2, we found that willingness to reduce flying and support for workplace policies to reduce flying were predicted by a sense of obligation (personal norm) and personal responsibility for reduced flying. While perceived behavioural control (family commitments and research activities that *require* flying) also exerted an influence, this was weaker than moral factors. Similar to Study 1, we found that climate change researchers, and those with children, who conduct fieldwork, and take more personal flights, also fly more for work. In our experiment, we found that providing information about the environmental impacts or social justice implications of aviation, including academic flying, increases behavioural intentions and support for institutional policies to reduce flying relative to a control. In addition, those with stronger environmental values and climate change knowledge were more willing to reduce flying and support institutional policies for reduced flying, across all conditions. The effects of information provision were not observed uniformly. Those with stronger environmental values were more likely to state an intention to reduce flying, in response to information about the environmental impacts of aviation. This is in line with models of pro-environmental behaviour theorising norm activation through problem awareness. Additionally, participants with lower levels of knowledge about the impacts of aviation were more likely to support policies to reduce flying, in response to this information. In contrast to the findings of Study 1 that climate change expertise inversely correlates with flying behaviour, this experimental result suggests a role of factual information in shaping attitudes for those less aware of the environmental impact of flying. We also observe a significant interaction between environmental values and justice-framed condition, whereby those with stronger pro-environmental values are more responsive to this information.

4.2 Discussion and implications

We find that – in both studies – climate change researchers (who have high climate change knowledge) actually travel and fly *more* than other researchers. That is consistent with previous research finding that climate change knowledge often does not predict behaviour (Whitmarsh et al. 2011; Balmford et al. 2017). At the same time, climate change researchers have replaced some flights with other travel modes or virtual attendance, tend to offset more often, and show a greater willingness to pay more for non-aviation alternatives. Consistent with this, giving researchers information about the climate change or social impacts of academic aviation increases willingness to fly less and support for policies to enable this – particularly amongst those with stronger pro-environmental values. However, our research makes clear that knowledge alone is insufficient to change workplace travel choices, and in fact those with arguably the most knowledge of all – climate change professors – fly more than any other group. Although attitudinal factors (e.g., personal norm) predict *willingness* to reduce flying, the strongest predictors of *actual* professional travel appear to be more social and structural, and include geography (European researchers fly less than those elsewhere, presumably due to available non-aviation alternative modes), family commitments (Study 2 found those with children fly more, perhaps to reduce time away from family), seniority (professors fly more than other researchers) and personal travel (both of which may indicate an effect of income). These relationships have also been found in previous studies of academic travel (Balmford et al. 2017, Ciers et al. 2019). This final predictor (personal flights), is intriguing, as it might also suggest that the type of people who choose to study climate change are more interested in international issues and in visiting other parts of the world – and as such, travel more both personally and professionally; or it might be an effect of a third factor, such as income or habit, which predicts both personal and professional aviation (Balmford et al. 2017, Verplanken et al. 1997). However, as this relationship is correlational, we cannot determine causality; this could be explored in future research.

Our finding that senior academics fly more than junior researchers, irrespective of their field of research, is counter to the argument that junior researchers are better-justified in flying given the need to establish a career and networks (Le Quéré et al. 2015). Conducting fieldwork (which is more common amongst climate change researchers than other disciplines) often demands significant travel, while 'conference culture' is central to most disciplines and for many travel is seen as a 'perk' of academia. In fact, one study suggests dissemination accounts for a much higher proportion of sustainability researchers' carbon footprint than conducting research (Waring et al., 2014), which may explain why conducting fieldwork was only one factor that predicted academic travel in our study. Many also feel that the quality of interaction is higher for face-to-face meetings, compared to virtual meetings; and indeed, our respondents largely viewed virtual options as inferior to physical interactions (although this was less the case amongst those who used them more often). This is consistent with previous research that finds academics' virtual interaction is not a substitute for physical interaction, but more often a supplement (Higham et al. 2019); indeed, information and communication technologies have been found to generate (rather than replace) travel demand for various reasons, including by expanding professional networks (van Wee 2015). On the other hand, benefits of reduced academic travel include more time for other work activities (e.g., research), improved gender and regional equality, work-life balance, and lower costs, as well as lower CO_2 emissions (Høyer and Naess 2001). This would suggest a need for investment in virtual options to improve their reliability and their ability to simulate the benefits of face-to-face interactions.

Our analysis also found a need for other travel modes to be improved in order to make them as attractive, or more so, than flying. Flying is seen as cheaper, faster and easier than alternatives; yet there is broad willingness to replace short-haul flights with non-aviation modes, even if this takes somewhat longer and costs slightly more. That people are willing to spend some more time travelling by non-aviation modes, but are less willing to pay more to do so, highlights a need for policy-makers to focus on making lower carbon modes more financially attractive in order to encourage modal shift.

Given the potential role of climate change researchers to advocate for low-carbon action and policy change (Attari et al. 2016, 2019), recent initiatives to develop a low-carbon research culture within climate science and the broader research community (Le Quéré et al. 2015, Hasan et al. 2018, FlyingLess 2019) need to be supported by broader policies and technologies to encourage and enable low-carbon and avoided travel. These policies might include information campaigns to highlight the environmental damage caused by aviation and the co-benefits of virtual participation (or low-carbon travel modes), but clearly this will not suffice to address the profound institutional, social and economic drivers of academic travel (including flying). Other measures should be implemented by governments to address aviation demand (e.g., carbon tax, frequent flyer levy); by academic institutions and funders to shift incentives away from international travel to more sustainable and inclusive research practices, including low-carbon conferencing; and by individual researchers in questioning the need or perceived ‘necessity’ for their travel and ensuring any travel considered justifiable (e.g., for scientific purposes, such as fieldwork) is organised efficiently to reduce emissions (Williams 2019, FlyingLess 2019).

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Author statement

Lorraine Whitmarsh: Supervision, Writing- Original draft, Writing- reviewing and editing, Conceptualization, Methodology, Visualization, Funding acquisition. **Stuart Capstick:** Writing- reviewing and editing, Conceptualization, Methodology, Visualization. **Isabelle Moore:** Investigation, Methodology, Formal analysis. **Jana Köhler:** Formal analysis, Writing- Original draft. **Corinne Le Quéré:** Writing-reviewing and editing, Conceptualization.

Supplementary Information

Study 2 Supplementary Information & Analyses

Demographic and professional characteristics of Study 2 sample

		%
Gender	Male	50.4
	Female	47.9
	Other/missing	1.8
Age	18-24	24.2
	25-34	56.4
	35-44	15.4
	45-54	2.8
	55-64	1.3
Country	UK	42.8
	USA & Canada	32.2
	Rest of Europe	20.9
	Other	4.0
Have children	No	82.6
	Yes (all)	17.4
	Yes – aged under 5	9.8
	Yes – aged 5-10	5.5
	Yes – aged 11-17	5.0
	Yes – aged 18 or over	2.3
Job role	Student	62.2
	Postdoc	19.6
	Assistant/Associate Professor	4.5
	Professor	1.0
	Other/missing	12.6
Discipline	Psychology	22.7
	Biology	19.2
	Engineering	12.1
	Chemistry	6.6
	Physics	5.8
	Economics	3.5
	Sociology	3.3
	Environmental science	1.5
	Other	25.3
Climate change knowledge	I don't know anything about climate change	0.3
	I know a little about climate change	23.2
	I know a fair amount about climate change	58.7
	I know a lot about climate change	16.6
	I am an expert on climate change	1.3

Work on cc / sustainability	No	78.5
	Yes – minor part	14.5
	Yes – major part	6.9
Conduct fieldwork	No	61.9
	Yes	38.1
Political ideology	Mean (0 = Left to 10 = Right)	4.44

Amount of travel undertaken

Mean number of flights in the last year for work was 7.15, compared to 8.04 personal/leisure flights. This includes domestic and international flights. Non-aviation international travel is less common at 4.25 and 4.76 trips for work and leisure, respectively. There is a significant correlation between work and personal flying, and between work flying and other travel.

Table S4. Means, standard deviations (SDs) and correlations of work and personal flights (Study 2)

	Work flights	Work non-aviation travel	Personal flights	Personal non-aviation travel
Mean	7.15	4.25	8.04	4.76
SD	2.96	2.56	3.02	2.67

	Work flights	Personal flights	Personal non-aviation travel
Personal flights	.507**		
Personal non-aviation travel	.291**	.389**	
Work non-aviation travel	.386**	.271**	.582**

**. Correlation is significant at the 0.01 level (2-tailed).

Attitudes to flying and climate change

Attitudes to flying are positive, and although there is acceptance that flying contributes to climate change, more responsibility is placed on government and industry than on personal academic travel (Table S6).

Table S6. Attitudes and beliefs in relation to flying (Study 2)

	Mean*	SD
If I fly for work, it is because flying is the quickest way of reaching a destination	6.04	1.25
Flying is the usual way of travelling long distances for work	5.94	1.36
If I fly for work, it is because flying is more convenient than other modes of transport	5.72	1.45
Aviation is a major contributor to climate change	5.28	1.53

Most of my colleagues fly for work	5.19	1.79
If I fly for work, it is because flying is the only possible way of reaching my destination	5.19	1.61
If I fly for work, this is because I value the opportunity to visit other parts of the world	5.14	1.67
If I fly for work, it is because I am expected to fly by my university/research project	4.87	1.78
The government and industry are primarily responsible for air travel emissions	4.79	1.50
I am concerned about the environmental impact of travel	4.76	1.70
If I fly for work, this is because flying helps me to maintain and develop research relationships and networks	4.76	1.81
I would support a policy in my workplace to encourage people to fly less for work	4.75	1.80
Academic travel contributes to climate change	4.73	1.64
If I fly for work, it is because flying is cheaper than other options	4.62	1.87
It is my university's/research center's responsibility to address the environmental impact of their employees' travel	4.57	1.65
I fly for work because it would limit my career progression if I flew less	4.48	1.86
I rarely consider the impact that my flying behaviour has on the environment	4.46	1.86
People like me should do everything they can to reduce how much they fly for work	4.36	1.72
Flying for work purposes is more justifiable than flying for personal purposes/leisure	4.26	1.77
I intend to reduce the carbon impact of my work-related travel	4.24	1.65
I don't feel guilty when I fly even though there are other feasible transport alternatives available	4.18	1.82
My own flying makes little difference to climate change overall	4.17	1.71
It would be difficult to carry out the research I need to if I did not fly	4.11	2.01
I would support a policy in my workplace to restrict the amount of flying employees do	4.11	1.81
I am not personally responsible for the flights I take for work purposes	4.06	1.62
I feel responsible for the environmental impact of my work-related travel	4.03	1.74
Any flying I do for work is made up for by environmentally friendly behaviors in other aspects of my life	3.93	1.64
I intend to reduce how much I fly for work in the future	3.70	1.76
My family commitments mean that I need to fly rather than use other means of travel	3.62	2.13
I do not give that much thought to my own carbon footprint	3.59	1.75
My family commitments mean that I have to limit the amount of travel I do for work	3.47	2.01
I feel obliged to travel less for work out of environmental concern	3.44	1.75
I would be a better person if I reduced the amount I fly	3.43	1.87
The environmental impact of the flights I take for work makes me feel guilty	3.38	1.78
If I fly for work, this is out of habit	3.19	1.79
I dislike flying	3.18	1.95
Changes in individuals' behavior make little difference to climate change overall	3.17	1.81

* Responses were on a seven-point scale from Strongly disagree (1) to Strongly agree (7)