


# Analysis of the Impact of Knowledge on Sustainable Travel Choices: an Empirical Study with Informational Videos and Gamified Quizzes

Syed Murad \* and Effie Lai-Chong Law

Department of Computer Science, Durham University, Upper Mountjoy Campus, DH1 3LE Durham, UK

\*Corresponding author: [syed.murad@durham.ac.uk](mailto:syed.murad@durham.ac.uk)

## Abstract

Carbon emissions from transport are increasing on a global scale with transport accounting for the largest portion. While there is greater awareness of climate change, few people are willing to change their travel habits. To gain a better understanding of this phenomenon, we were motivated to conduct a study to identify the obstacles encountered by travellers when opting for sustainable transport modes, assess their knowledge of carbon emissions from various transport modes and explore how this knowledge affects their decision-making process. The study employed mixed-method approaches, including the use of informational videos and gamified quizzes for intervention, pre- and post-intervention knowledge assessment tests, semi-structured interviews, observations, Self-Assessment Manikin for emotion measures and card sorting. The findings primarily derived from thematic analysis indicated that knowledge-based intervention can be a strong catalyst to encourage sustainable attitude and behaviour change. Insights so gained have important theoretical and practical implications for designing sustainable behaviour change in the future, especially the deployment of persuasive technology.

## RESEARCH HIGHLIGHTS

- The study provided deeper insights into the gap between climate change awareness and the continued preference for non-sustainable travel habits.
- A knowledge-based intervention was developed, incorporating informational videos and gamified quizzes to encourage sustainable transport choices.
- A mixed-method approach, including card sorting, interviews, and emotion analysis, was systematically applied to analyse sustainable attitudes and behaviours.
- The findings emphasized the potential of the Inverted Pyramid Model in fostering sustainable transport choices.

**Keywords:** *human-centred computing; sustainability; travel plan; behaviour change; persuasive; technology*

## 1. INTRODUCTION

Since the pre-industrial era, there has been a rise of  $>1^{\circ}\text{C}$  in global average temperatures (NASA Earth Observatory, 2023). Climate change is caused by the rising levels of carbon emissions; transport is accounting for approximately around one-fifth of total global greenhouse gas emissions (Statista, 2024). Global carbon dioxide emissions from the transport industry increased by  $>250$  million metric tons in 2022, reaching almost 8 billion metric tons, representing a 3% rise compared to 2021 (IEA, 2023a). The transport sector must reduce emissions by  $\sim 25\%$  by 2030 in order to achieve the Net Zero Scenario, despite a projected increase in transport demand (IEA, 2023b). It is now more crucial than before to encourage shifting to less carbon-intensive travel options, such as walking, cycling and public transport, in addition to more effective technologies, such as electric vehicles.

The transport sector is the leading source of greenhouse gas emissions, accounting for 26% of the total emissions in the UK in

2021. The COVID-19 pandemic and associated restrictions had a notable effect on domestic transport emissions in the past 3 years, with a 19% decrease in 2020, which was followed by subsequent increases after the restrictions were lifted. This pattern suggests that emissions from the transport sector could be mitigated by regulating human behaviours, but it needs effective strategies to promote sustainable travel behaviour (Dft, 2023). To address this ongoing challenge, it is crucial to explore the potential of technology and media in promoting sustainable transport practises. At its simplest form, a strategy for changing travel behaviour involves the sharing of information, communication, education and training to increase awareness with the aim of promoting changes in behaviour (Bamberg et al., 2011).

Travel behaviour change is an increasingly important area of research that has led to a variety of theories, behaviours and methodologies. The travel behaviour change approach has a long history, with the first article published in 1992, and it has

**Received:** March 30, 2024. **Revised:** September 5, 2024. **Accepted:** November 5, 2024

© The Author(s) 2024. Published by Oxford University Press on behalf of The British Computer Society.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

significantly grown since (Pawluk De-Toledo et al., 2022). A plethora of behaviour change theories within the domains of psychology, sociology, anthropology and economics have been developed (Davis et al., 2015). Nonetheless, commonly used behaviour change theories in transport studies, such as the Theory of Planned Behaviour and Transtheoretical Model (Section 2.1), are found inadequate, prompting the exploration of alternative models.

Recently, persuasive technologies like mobile apps have emerged as effective tools for promoting sustainable transport practises (Anagnostopoulou et al., 2018). Additionally, researchers propose that mobile apps are more readily available to a broader range of users, including older adults (Murad et al., 2012). Personalized travel plans, web and app-based tools are the primary methods being tested in this area to implement informational strategies. Persuasive technology, pioneered by Fogg in 2003, aims to influence user attitudes and behaviours without coercion. Anagnostopoulou et al. (2018) reviewed literature up to early 2018 and found that persuasive technologies significantly impact sustainable transport choices. Fogg's behaviour model, highlighted in 2022, underscores the importance of motivation, ability and triggers for behaviour change (Section 2.2). These theoretical models have informed empirical studies in the last three decades, which aimed to identify ways to change people's behaviour towards sustainable choices in the areas of transport, energy and so on (Froehlich et al., 2009; Foster et al., 2010; Froehlich et al., 2010; Harries et al., 2013; Anagnostopoulou et al., 2018; Pawluk De-Toledo et al., 2022). Nonetheless, it remains a challenge for various reasons. Amongst others, one key observation is that using a motivational technique is not enough; different habits require different motivations and abilities.

Overall, none of the prevailing models have led to interventions that could consistently promote sustainable behaviour change, indicating that there are elements missing in the existing pro-environmental behaviour models. It is intriguing to understand how different types of travellers make their transport choices. Amongst them, academic business travellers (ABTs) are a specific type with unique characteristics, including tight budget constraints, work culture and attitudes towards research information.

A recent research study has identified ABTs' knowledge, planning strategies and mental models for business travel as potential areas for improvement in promoting sustainable travel behaviour (Murad and Law, 2023). They have highlighted that ABTs are not motivated by sustainability when choosing transports. Particularly astonishing is that the understanding of sustainability and transport carbon emissions amongst ABTs was notably poor. This is unexpected as academics in their study were well educated with the inclination to explore different kinds of knowledge. Nonetheless, this stereotypic generalization seems refutable, given the results of the study (Murad and Law, 2023). It is intriguing to find out whether such a lack of knowledge is prevalent amongst travellers in general, going beyond the scope of the work by Murad and Law (2023).

Based on the phenomena described above, the main goal of the study reported in this paper is to develop an in-depth understanding of the impact of knowledge on travellers' preference for sustainable transport options, inferring theoretical and practical implications to inform future endeavours along this inquiry. Specifically, our work aimed to explore the following three research questions (RQs) with mixed methods, including semi-structured interviews and pre- and post-intervention surveys (Section 3):

- 1) What is the level of knowledge about carbon emissions of transport options amongst travellers?
- 2) How can the knowledge about carbon emissions of transport options influence travellers' decision-making process and their willingness to choose sustainable transport options?
- 3) What are the theoretical and practical implications for promoting sustainable behaviour change, given an enhanced understanding about the impact of knowledge on attitudes towards sustainable transport options?

Overall, our work presented in this paper contributes to three main areas:

- **Theoretical:** We conducted a thorough review of existing theoretical frameworks on behaviour change, identifying their strengths and weaknesses, particularly in relation to sustainable travel. Through empirical data collection, we gained further insights into these models and explored adaptations of Fogg's models to inform future research in this domain.
- **Methodological:** Our mixed-method approach, which integrates intervention (i.e. informational videos and gamified quizzes) and evaluation (i.e. card sorting, semi-structured interviews and pre- and post-travel plan design) in a coordinated workflow, proved highly effective. This was evidenced by participants' positive feedback and insightful responses. We believe this methodological approach can serve as a valuable blueprint for adaptation and application within the research community.
- **Practical:** Our intervention design was well received by participants, suggesting its potential to inspire the development of future systematic interventions, such as a gamified mobile app focused on sustainable travel.

## 2. RELATED WORK

### 2.1. Theoretical models and empirical studies on behaviour change

Design for behaviour change focuses on how design can impact and shape human behaviour as well as sustainable innovation (Lockton et al., 2010; Parajuly et al., 2020; Niedderer, 2022). Key areas where it is applied encompass sustainability, public health and wellness and social environments (Grilli and Curtis, 2021). The primary behaviour change theories commonly applied in transport studies have been the Theory of Planned Behaviour (Ajzen, 1991) and the Norm-Activation Theory (Schwartz, 1977), the Transtheoretical Model or Stages of Change Model (Prochaska and DiClemente, 1983) and the Rational Choice model (Bertolini, 2005). The Social Marketing Framework has been applied to develop travel behaviour change interventions (Davies, 2012).

In recent years, a variety of established theories, approaches and tools are utilized to promote environmentally friendly and socially responsible actions and behaviours amongst designers and users. The design approach for influencing behaviour known as the 'Loughborough model' (Tang and Bhamra, 2008; Lilley, 2009) aligns closely to behavioural economics; it incorporates elements like feedback loops and constraints and affordances as well as persuasive technology. Ludden and Hekkert (2014) were influenced by the Transtheoretical Model as a basis to develop a new framework for designing healthy behaviour. The framework illustrates that designers must take into account the various phases that people go through to durably change their behaviour. Their model for creating designs that promote healthy behaviour includes four distinct design approaches spanning various phases: 'increasing awareness', 'facilitating', 'inspiring' and 'gradually phasing out'.

Several systematic reviews have indicated that current behaviour change programmes can decrease private motor vehicle trips by 5–15% (Möser and Bamberg, 2008; Brög et al., 2009; Chatterjee, 2009; Scheepers et al., 2014; Petrunoff et al., 2016; Semenescu et al., 2020; Okraszewska et al., 2024). However, behaviour change tools are frequently applied together, creating challenges in identifying the specific factors that impact behaviour change (Scheepers et al., 2014). Researchers, based on the results of the systematic reviews, have highlighted the lack of consistent quality research in this field, given the drawbacks identified, including small sample sizes, short study durations and lack of controlled before-and-after or randomized control research designs (Chatterjee, 2009; Graham-Rowe et al., 2011; Petrunoff et al., 2016; Anagnostopoulou et al., 2018; MacInnes et al., 2022).

As the evidence suggests, those behaviour models are unsuccessful in informing strategies for behaviour change and it is essential to investigate other behaviour models (Froehlich et al., 2010; Pawluk De-Toledo et al., 2022). There are still significant challenges regarding the lack of standardized terminology, formalized research protocols and the selection of target behaviours within these approaches; thus there are substantial prospects for further research on behaviour change in transport choices, as well as for developing new models or theories related to behaviour change (Zachrisson and Boks, 2012; Pawluk De-Toledo et al., 2022).

## 2.2. Persuasive technology

Persuasive technology is broadly defined as technology that is designed to change attitudes or behaviours of the users through persuasion and social influence, rather than through coercion (Fogg, 2003; Wang et al., 2023). Various persuasive methods employing diverse methods like behaviour feedback, social comparison, goal setting, gamification, personalized recommendations and challenges have been employed to date. Furthermore, new approaches are consistently in development. Anagnostopoulou et al. (2018) conducted a thorough analysis of literature spanning from 2003 to early 2018, concentrating on the domains of Persuasive Technologies, Personal and Multi-Modal Mobility and Transport Behavioural Change. They have highlighted that even though it is difficult to forming a firm judgement on the lasting effects of persuasive technologies because of lack of information available, there is clear evidence that persuasive technologies have significant potential in encouraging sustainable transport choices and influencing behaviour change. In recent years, a persuasive interaction design model called Fogg's Behaviour Model (Fogg, 2022) has shown potential in encouraging behaviour. This model suggests that an individual must have sufficient motivation, appropriate ability and an effective trigger for a target behaviour (Ali et al., 2023). Fogg's behavioural model (Fogg, 2003) for persuasive technology is informed by various theories from psychology and computing. Fogg's work was influenced by prior studies such as the work of Reeves and Nass (Reeves and Nass, 1996) on how people relate to computers and interfaces as if they were 'social actors' (Niedderer et al., 2014; Niedderer et al., 2017). Fogg's model of persuasive technology focused on motivating behaviour, with attitude change either as a precursor or a result.

## 2.3. Sustainable travel behaviour change

Sustainable travel behaviour change aims to promote and encourage individuals to adopt more sustainable modes of transport, such as walking, cycling or using public transport

(Andersson et al., 2018). To achieve this goal, various strategies are implemented, such as design for behaviour change, travel behaviour change programmes, persuasive technology, awareness campaigns, incentives and infrastructure improvements (Ruiz et al., 2018; Gupta et al., 2021; Glasgow City Council, 2023). Strategies are designed to change people's attitudes and intentions towards sustainable transport choices, with the goal of decreasing reliance on cars and flight and bringing about environmental advantages. Travel Behaviour Change Programmes often incorporate 'soft' transport interventions, which involve providing information about alternative transport options, as well as offering appropriate support, motivation and disincentives for car use (Piras et al., 2022). Travel Behaviour Change Programmes that focus on soft transport measures such as Personal Travel Planning, travel feedback programmes and persuasion strategies have been found to contribute to substantial decreases in car usage (García-Garcés et al., 2015; Skarin et al., 2017; Sottile et al., 2021). These measures have the potential to achieve more economical results by lowering car dependency and encouraging sustainable transport choice; however, previous efforts to utilize incentives as a means of promoting sustainable transport options such as car usage have not proven to be effective (Ruiz et al., 2018).

As discussed above, persuasive technologies like mobile apps and web platforms have been used to promote sustainable travel behaviour. We have identified that in recent years, there has been an increase in the development and use of mobile applications and web platforms that aim to promote sustainable travel behaviour. Some examples of these mobile apps or web platforms include (Table 1):

Based on the information provided in these research studies, technology such as mobile app and web, personalization, contextualization, gamification, rewards and proactivity can improve the effectiveness of persuasive interventions for attitude and behaviour change towards sustainable transport choices. However, there seems limited evidence demonstrating systematically people's change of attitude or behaviour towards sustainability as a result of knowledge gain. This gap has motivated us to assess participants' pre- and post-intervention level of understanding of the related topics in our empirical study, which is described in the following section.

## 3. METHODS

The main goal of this empirical study was to understand the impact of knowledge about carbon emissions of different transport options on travellers' preferences for sustainable transport options. An ethics application for the study has been submitted to the ethics committee of Durham University, and an ethics approval has been granted.

### 3.1. Participants

Participants for this study were sourced from UK travellers who travelled at least two trips annually, whether for business or pleasure purpose. We promoted our study through social media groups and utilized mailing lists to recruit participants. The study recruited a total of 30 participants, comprising 15 males and 15 females, with ages ranging from 18 to 62 years. On average, they have travelled 9.3 business trips and 49 pleasure trips. We have refrained from including specific details and the terms 'knowledge' and 'sustainability' in our advertisement. In addition, participants were instructed not to reveal any information about the aim of the study, study process and sustainability in order to prevent bias. Therefore, the study was able to collect

**Table 1.** The persuasive technologies to promote sustainable travel behaviour identified in the literature.

System name (Source)	Platform	Persuasive techniques	Aim
SMART (Huang et al., 2021)	Mobile app	Gamification, rewards	To assist individuals in making more informed transport choice decisions, such as steering clear of traffic congestion or selecting alternative modes of travel
SPARROWS (Ahmed et al., 2020)	Web-based	Personalized feedback	To encourage changes in individual travel behaviour, promoting environmentally conscious and health-friendly behaviour
OPTIMUM (Tsirimpa et al., 2019)	Mobile app	Self-monitoring, comparison, suggestion	To encourage users to choose more environmentally friendly routes
SaveMyBike (Petri et al., 2018)	Web-based	Rewards, self-monitoring	To encourage individuals to choose sustainable modes of transport in urban areas and to improve air quality
GreenCommute (Wu et al., 2018)	Web-based	Rewards, social comparison	To help commuters make environmentally friendly decisions for choosing sustainable transport options
EcoTrips (Park et al., 2017)	Mobile app	Self-monitoring	To promote walking and cycling for shorter trips

unbiased responses from a diverse group of frequent travellers. Participants recruited had diverse backgrounds, including five IT professionals, four members of management, four academics, three who work within the hospitality industry, three students, two from the healthcare sector, two from the quality control field, two management information systems professionals, two from the human resources/admin sector, one designer, one from the marketing sector and one business owner. This heterogeneity could not only broaden the scope beyond academic travellers as studied by Murad and Law (2023) but also mitigate biases. None of them had any disabilities that would limit their transport choices or affect their ability to travel. All participations were voluntary without any compensation.

### 3.2. Instruments

The study employed a mixed-method approach, utilizing different tools and methods for intervention (i.e. informational videos, games), knowledge testing (i.e. card sorting, pre- and post-intervention tasks), data collection (i.e. semi-structured interviews, observation, self-assessment manikin (SAM)), and data analysis (i.e. thematic analysis, including card sorting). Here we give an overview of the tools of which details are provided when the results are presented in Section 4.

- Card Sorting: A method that involves asking participants to organize information into logical groups or hierarchical order (Sherwin, 2018). It was used in this study to understand participants' awareness of carbon emissions for transport.
- SAM: A widely used tool for assessing emotional responses, grounded in the established theory arguing for three dimensions of emotion, namely valence, arousal and dominance (Bradley and Lang, 1994). It was used in this study to gauge participants' emotional responses to the interventions presented.
- Informational video: The human brain can process visuals faster therefore using visual learning tools such as videos is an effective way to convey information and engage people's attention (Bărbuceanu, 2020). The video component of the study involved showing participants information about global carbon emissions effects on environment and transport carbon emissions in the UK (Section 3.3.2).
- Self-assessment game: Games are widely deployed not only for entertainment but also for other purposes such as

education and health training (Nacke et al., 2009). This study's game was designed to engage participants in a fun and interactive way to self-access the knowledge received from the video.

- Pre- and post-intervention tasks: It involved asking participants to plan a travel route, allowing researchers to assess their pre- and post-knowledge, intentions, attitudes and considerations regarding transport choice.
- Semi-structured interview questions were used to gather more in-depth information and insights from the participants. The audio recordings were transcribed.
- Thematic analysis was then conducted to analyse and interpret the qualitative data collected from the interviews, as well as to identify key themes and patterns (Boyatzis, 1998; Aronson, 1995).

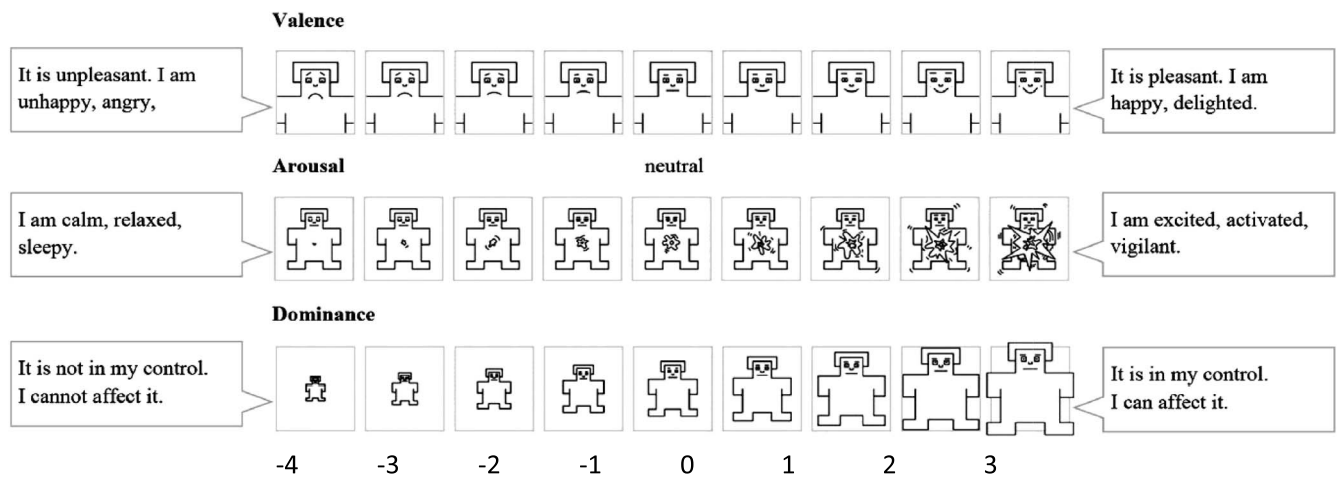
### 3.3. Procedure

The research comprised two stages. Stage One aimed to understand pre-knowledge travel planning strategy, behaviour and knowledge about carbon emissions for transport. Stage Two aimed to examine the impact of knowledge on travel behaviour and its effects. There was no time constraint imposed at any stages of the study. The study took on average 47 min to complete.

#### 3.3.1. Stage one: pre-knowledge planning and carbon emissions knowledge

To understand their pre-knowledge of carbon emissions for transport, participants were given a set of cards representing different modes of transport and asked to arrange them based on carbon emissions per passenger per kilometre (i.e. Card Sorting method). Additionally, to gain insights into participants' prior knowledge and mental models regarding travel planning, individuals were requested to plan a trip from the Scottish National Gallery of Modern Art in Edinburgh (Modern One) to Alexandra Palace in London, with the requirement that they do not return on the same day. Participants were given the freedom to use the internet, seek advice from others (e.g. friends, family, colleagues) and rely on their previous knowledge throughout the planning. They were asked to think aloud during the entire process.





**Figure 1.** SAM scales (adapted from Bartosova et al., 2019).

### 3.3.2. Stage two: knowledge assessment

With the aim to enhance participants' understanding of the relevant topic, they were presented a pre-recorded YouTube video entitled 'Global Carbon Emissions Effects on Environment and Transport Carbon Emissions in the UK', developed by the authors<sup>1</sup>. All information presented in the video was supported by research and cited from credible sources such as NASA Goddard Institute for Space Studies, Department for Energy Security and Net Zero, [OurWorldInData.org](https://www.ourworldindata.org). Furthermore, the video was designed to cater to different learning styles, incorporating visual, auditory and kinaesthetic elements (Gilakjani, 2012). To ensure clarity and ease of understanding, the information within the video was structured according to the principle of information architecture (Brown, 2010). The details provided were organized in a logical manner, allowing for easy comprehension and navigation.

The video is divided into four parts:

- Part 1 'Information and Current Effect on Climate Change' is an introduction to CO<sub>2</sub> emissions and climate change. The video then provides information and data on CO<sub>2</sub> emissions, climate change and global warming from the years 1850–2021 and evidence of climate changes at the present time.
- Part 2 'Future Consequences' provides an analysis of future scenarios based on historical data, projecting the potential consequences in the years 2050 and 2070. Additionally, it highlights the long-term impacts that climate change may have on various aspects.
- Part 3 'the United Kingdom's CO<sub>2</sub> Emissions and Transport' provides historical carbon dioxide emissions data in the UK, sector-specific CO<sub>2</sub> emissions and CO<sub>2</sub> emissions from various modes of transport.
- Part 4 'Information about CO<sub>2</sub> Emissions of Different Transport Methods' delves into the information about CO<sub>2</sub> emissions of different transport modes and provides information on the difference in emissions between various transport methods when travelling from Scotland to London, provided by Department for Transport, UK (2023).

At the end of each part of the video, participants were instructed to complete the SAM scales and provide a word to indicate their emotional state (Fig. 1).

For Valence, how positive or negative the emotion is, ranging from unpleasant to pleasant with a set of nine stylized human-like figures (manikins) depicting feeling very unhappy or angry (score of –4) to neutral (score of 0) to very happy or delighted (score of 4). For Arousal, how excited or apathetic the emotion is, ranging from calm, sleepy or relaxed to excited, activated or vigilant with a set of nine stylized human figures (manikins) depicting this emotional dimension on a scale of –4 to 4. For Dominance, the extent to which the emotion makes the participant perceive they are in control of the situation, ranging from not at all in control to totally in control. Also, a set of nine stylized human figures (manikins) depicts this dimension on a scale of –4 to 4.

To reinforce the information presented in Part 4 of the video, participants were asked to play two interactive games. These games aimed to enhance memory retention, improve understanding of different transport modes based on their respective carbon emissions and develop the ability to identify these modes accurately. The first game required participants to choose the correct CO<sub>2</sub> emissions per passenger per kilometre from three different options for eight different modes of transport. The game would not progress to the next transport until the correct option was selected. The second game involved arranging the eight transport modes in an ascending order based on their carbon emissions (Fig. 2). Participants would complete the game when all transports were placed in the correct order.

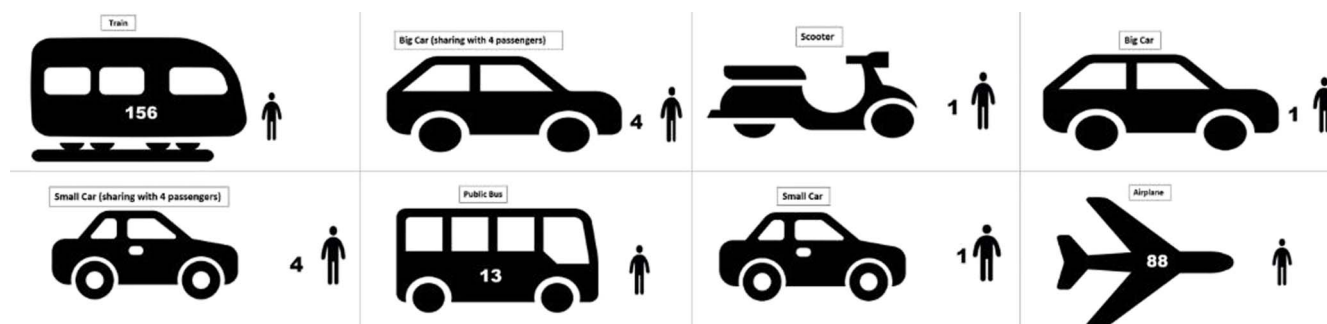
In this part of Stage two, participants were instructed to revise their travel plans for the trip from the Scottish National Gallery of Modern Art in Edinburgh (Modern One) to Alexandra Palace in London and back, while keeping the same conditions as their initial planning. Participants were also asked to complete a sustainability consideration measure form for each mode of transport they had chosen in their revised travel plans.

In the final part of Stage One, a one-to-one semi-structured interview was conducted. The entire process was audio- and video-recorded using a technology call Swivl.

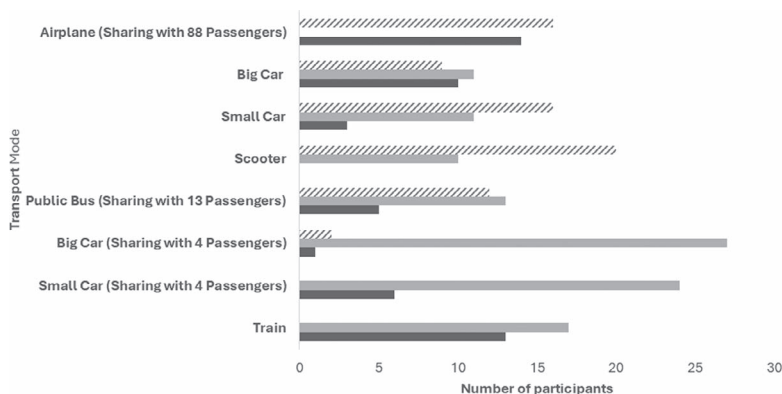
## 4. RESULTS

In this section, we present the results in the order in which the intervention tools and data collection methods were administered in the empirical study. The data underlying this article will be shared on reasonable request to the corresponding author.

<sup>1</sup> The link to the video will be shared upon request.



**Figure 2.** Knowledge assessment game of sorting CO<sub>2</sub> emissions of different transport modes.



**Figure 3.** CO<sub>2</sub> emission for individual transport modes: underestimated by participants (striped), overestimated by participants (grey) and actual (black).

#### 4.1. Understanding pre-knowledge CO<sub>2</sub> emission for transport mode

The results were derived from the data of the Card Sorting exercise in the pre-knowledge stage. None of the participants were able to accurately rank the transport modes based on their CO<sub>2</sub> emissions (Fig. 3).

Only 13 out of 30 participants correctly identified the train as having the lowest environmental impact in terms of carbon emissions; 24 participants overestimated the CO<sub>2</sub> emissions for a small-shared car and 27 participants overestimated the emissions for a large-shared car. Out of the participants, only five were able to correctly identify the public bus. For the scooter, none of the participants correctly identified its impact on CO<sub>2</sub> emissions, with 20 participants underestimating its emissions. In addition, 3 participants correctly identified the small car, 10 participants correctly identified the large car and 14 participants correctly identified the airplane as having higher CO<sub>2</sub> emissions. The findings from the pre-knowledge stage revealed that participants had a limited understanding of the CO<sub>2</sub> emissions associated with different modes of transport. It was observed that female participants demonstrated a higher accuracy in identifying the CO<sub>2</sub> emissions associated with different modes of transport compared to male participants. Moreover, the findings revealed that participants in the older age group achieved a higher accuracy in identifying CO<sub>2</sub> emissions compared to those in the younger age group.

According to a study by Murad and Law (2023), ABTs did not accurately categorize the transport modes based on their CO<sub>2</sub> emissions. ABTs had an overall accuracy rate of 31% and the participants of this study had the accuracy rate of 22%. Both groups displayed a limited understanding of CO<sub>2</sub> emissions for different transport modes except airplanes: 80% of ABTs correctly identified airplanes as the highest carbon contributor

whereas only 47% of participants in this study successfully identified it. For smaller shared cars and small cars, the difference in accuracy between ABTs and general travellers ranged from 0 to 10%. For larger shared cars, the difference was between 11 and 20%, and for public buses and scooters, the difference ranged from 21 to 30%. The study also found that none of the ABTs correctly estimated public buses, and none of the general travellers correctly estimated scooters in terms of their CO<sub>2</sub> emissions (Fig. 4).

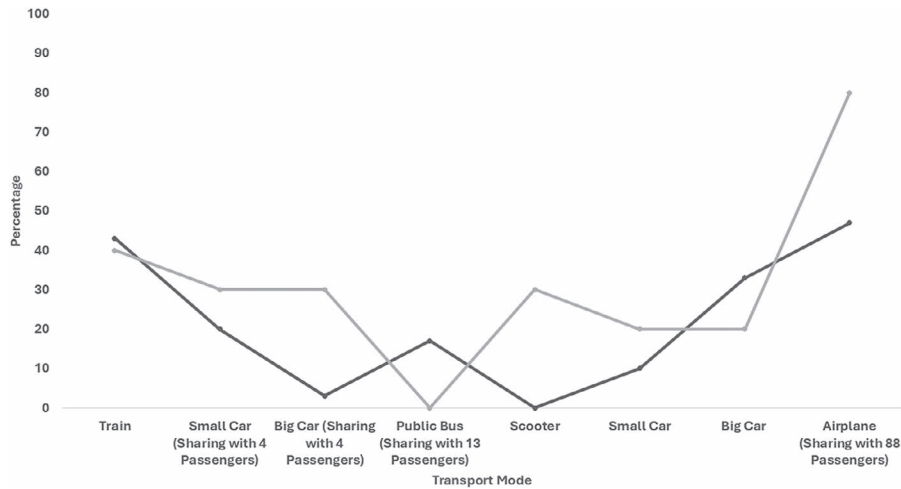
#### 4.2. Pre-intervention travel planning

##### 4.2.1. Quantitative data analysis

We analysed 30 pre-knowledge travel plans and categorized them into three groups based on the modes of transport chosen and their sustainability ranking. The three categories are:

- *Highly sustainable choice:* Examples include train and shared vehicles. Limited or no potential for alternative choices of change in transport choices.
- *Medium sustainable choice:* Examples include public bus and scooter. In some cases, taking a bus can be highly sustainable if no other feasible alternatives are available. There is potential for some level of change in transport choices.
- *Low sustainable choice:* Examples include flights and motorized personal vehicles for individual users instead of shared ones. There is a high potential for change in these choices.

In addition to the ranking based on sustainability, the modes of transport are further divided into two categories: primary transport and secondary transport. Primary transport refers to the main mode of transport used for travelling to and from the destination, while secondary transport includes the additional modes used for primary transport within the destination and during the trip.



**Figure 4.** CO2 emissions for transports accuracy comparison between ABTs (grey) versus general travellers (black).

**Table 2.** Transport chosen and sustainability ranking.

Transport mode	High	Medium	Low	N/A
Primary transport(s)	17	3	10	N/A
Secondary transport(s)	12	5	11	2

For primary transport, there were 17 highly sustainable choices, 3 transport choices were considered medium sustainable and 10 transport choices were classified as low sustainable options. Out of these 10 low sustainable choices, 7 were flights, 2 were personal cars and 1 was a van (Table 2).

For secondary transport, there were 12 highly sustainable choices, 5 medium sustainable choices and 11 low sustainable choices. There were two situations in which secondary modes of transport were not selected due to the initial choice of primary transport that made secondary transport unnecessary (i.e. 'N/A' in Table 2). Taxis and cars were the most common low sustainable choices for secondary transport.

On average, participants spent ~257 s (4.3 min) on planning their journey. When considering the primary transport sustainability choice, the average time spent on planning for highly sustainable and medium sustainable choices was similar, at ~297 and 295 s (almost 5 min), respectively. However, for low sustainable choices, the average time spent on planning was significantly lower at 179 s (3 min). Furthermore, it is worth noting that for 7 out of 10 participants who made low sustainable transport choices, the time spent on planning their journey was <100 s (1.7 min). The data indicates that there is a trend of participants spending less time on planning when it comes to low sustainable transport choices.

According to the study of Murad and Law (2023), participants made their transport choices using four different types of decision-making processes. These included habitual selections, as seen in 7 participants; experience-based selection, which was used by 8 participants; motivation-based selection, which was adopted by 10 participants; and a combination of experience-based selection with motivation-based selection, which was observed in 4 participants and a combination of experience-based selection with knowledge-based selection as seen in 1 participant. These findings suggest that participants' transport choices were influenced by their habits, past experiences, motivations and a combination of experience and knowledge (Table 3).

**Table 3.** Distribution of decision-making processes for transport choices.

Decision-making processes	Frequency (%)
Experience-based selection with knowledge-based selection	1 (3%)
Experience-based selection with motivation-based selection	4 (13%)
Habitual selections	7 (23%)
Experience-based selection	8 (27%)
Motivation-based selection	10 (33%)

#### 4.2.2. Qualitative data analysis

We analysed participants' responses with thematic analysis; the following four themes are identified (Table 4). When participants were questioned about the key factors that motivated their transport choices, 'cost' (17 times), 'convenience' (17 times) and 'time' (16 times) were frequently cited. All seven participants who chose flights as their primary mode of transport did not take into account the time required for boarding and potential additional travel time to and from the airport. They only considered the actual flight time for domestic flights, neglecting other factors such as airport procedures and transport logistics.

#### 4.3. Informational video

##### 4.3.1. Emotional responses

Overwhelmingly all participants expressed positive feedback regarding the informational video, stating that it was informative, reliable, easy to understand and had a lasting impact on them. Participants were asked to indicate their emotions using a single word. For Part 1, the most commonly expressed emotions are: 'concerned', 'shocked' and 'worried' whereas for Part 2 they are 'concerned', 'sad' and 'worried'; for Part 3 are: 'guilty', 'surprised' and 'responsible'; for Part 4 are: 'surprised', 'informative' and 'informed'. For the overall informational video, the most commonly used words are 'surprised', 'concerned', 'guilty', 'shocked' and 'worried'. This suggests that the video had a significant impact on participants, evoking strong emotions and increasing their awareness of the issue of CO2 emissions and its relation to transport methods. Further information is visualized in Fig. 5.

We measured participants' valence, arousal and dominance for each of the four parts and the entire video (Section 3.3.2). Descriptive statistics values are displayed in Table 5 and the trend is

**Table 4.** Themes identified based on participants' responses to transport choices.

Theme	Example quote
Focus on efficiency and speed	<i>'I'd been open and honest is about efficiency of time. The reason behind that is obviously job and family.'</i> (P29) <i>'It's all about getting from one location to another in the quickest way possible.'</i> (P23)
Consideration of comfort and cost	<i>'I will do whatever is more comfortable for me.'</i> (P12)
Scepticism towards public transport	<i>'I heard people discuss about using public transport, I think they said they can't trust.'</i> (P14)
Personal negative experiences	<i>'I wouldn't take the coach because it takes forever ... Last time the suspension was really bouncy, and I felt so sick, so I'd always rather pay more and get the train.'</i> (P27)



**Figure 5.** Emotional words expressed for the informational video. The size of each word varies based on how frequently it appears in participant responses.

illustrated in Fig. 6. While participants responded to all parts with negative valence (pleasure), Part 2 describing future consequence elicited the most negative rating (Mean =  $-2.33$ , SD =  $1.1$ ). These were corroborated by the negative emotional words such as guilty, concerned, worried and shocked. They were slightly excited and felt in control of the situation, as shown by the low overall average of arousal (Mean =  $0.93$ , SD =  $1.96$ ) and dominance (Mean =  $0.87$ , SD =  $1.01$ ).

We observed that participants were engaged and attentive while watching the video. During the experiment, 23 participants exhibited strong engagement through physical movements such as leaning over and displaying various facial expressions, including nodding in agreement. One participant exhibited minimal facial expressions and showed little response but leaned closer to the screen. Three participants were leaning back or maintaining

distance from the screen while displaying different facial expressions and nodding in agreement. Three participants exhibited a lack of engagement as evidenced by leaning back or maintaining distance from the screen, displaying minimal facial expressions and limited nodding.

#### 4.3.2. Cognitive responses

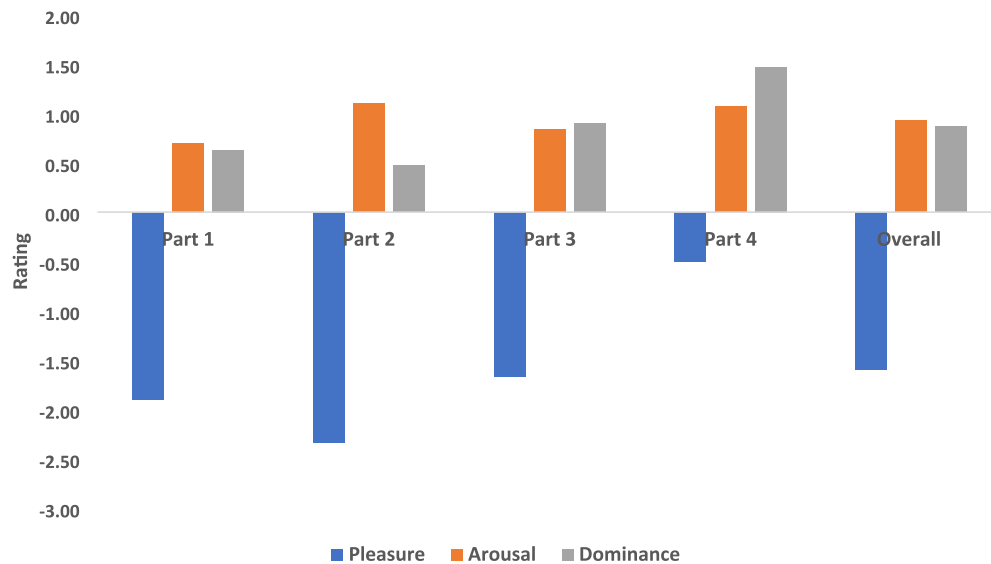
All participants, irrespective of their prior knowledge, regarded the video as both educational and enlightening. This suggests that the video effectively communicated information to all participants, regardless of their existing knowledge of the topic. This finding highlights the ability of the video to effectively educate and inform individuals with varying levels of prior knowledge. They have also highlighted that the graphical representation with the audio and visual aids used in the video greatly contributed to their understanding and retention of the information presented. Participants mentioned that they held incorrect beliefs about certain modes of transport, such as mistakenly thinking that airplanes have lower emissions than they do. Overall, participants were surprised at how car share can lower emissions and contribute positively to reducing their carbon footprint and promoting sustainability. Additionally, the participants have emphasized that there is a negative tone in current news and media coverage. They believe that creating more videos like this would be an effective way to effectively communicate information. Furthermore, respondents emphasized the need for greater government involvement in promoting sustainability. This includes raising awareness about the benefits of sustainable transport options, enhancing transport infrastructure and implementing effective policies to support sustainability efforts. Out of the 30 participants, only two claimed to have a sufficient understanding of sustainability but not about transport before viewing the video. With thematic analysis, five themes were identified from the comments on the video (Table 6).

With the knowledge gained, the video also had other impacts on the participants, such as being more environmentally friendly; intention to change or rethink their transport choices; understanding and relating transport choices to their travel and their emission; a better understanding of plane, train, car and car share emissions and their impact on the environment; and a stronger motivation to actively promote and pursue sustainable transport

**Table 5.** Valence (V), arousal (A) and dominance (D) amongst participants for the informational video.

	Part 1			Part 2			Part 3			Part 4			All parts		
	V	A	D	V	A	D	V	A	D	V	A	D	V	A	D
Mean	−1.9	0.7	0.6	−2.3	1.1	0.5	−1.7	0.8	0.9	−0.5	1.1	1.5	−1.6	0.9	0.9
SD	1.4	1.3	2.0	1.4	1.5	2.1	1.4	1.4	1.9	1.8	1.2	1.9	1.1	2.0	1.0





**Figure 6.** SAM ratings for the four parts of the video and overall.

**Table 6.** Five themes identified from the comments on the video with example quotes

Themes	Examples of comments
<b>Impact of information:</b> The video has a significant impact on the viewers, enhancing their knowledge and prompting them to reflect on their behaviours and choices, particularly in relation to transport and its environmental implications.	<i>'It definitely highlights that there is a huge problem, obviously. Good use of metrics, statistics, predictions, things like that definitely do bring out some alarming facts about global warming and transport.'</i> (P4) <i>'The video is very detailed, very factual with the use of visuals and data; information provided was clear and precise ... from having zero knowledge of this topic area I was able to grasp key knowledge very quickly and articulate with my own experience of travelling what is my CO2 emissions are.'</i> (P15) <i>'I think that when you see the statistics and the impact that the CO2 is having and could have on the environment in 2050. I think again it's sad really, because it could change, it doesn't have to be like that, does it. I think it's about education.'</i> (P17) <i>'I don't pay any attention really to sustainability when it comes to travel choices. Having it spelled out to you like that does make you think that you know, it is a consideration. And if everybody did that then we could go some way to lowering carbon emissions.'</i> (P30) <i>'I was actually amazed that train was lower emission than bus. I thought it was the other way around.'</i> (P5) <i>'Even though I've heard people saying the plane is bad, but I've not really thought how bad it is. So, it is an eye opener, especially with the cars share.'</i> (P3) <i>'I tend to drive a lot. It was a bit shocking how much it contributes.'</i> (P6) <i>'First, I thought it like similar negative coverage as you see in the news. Then with the detailed information on the emissions, actually that was quite interesting because it was personally applicable.'</i> (P13) <i>'I read about CO2 emissions; I think I was maybe a denialist... But the way information presented to me today I am convinced, and I can see how wrong I was.'</i> (P19) <i>'There's a debate on whether climate change is real at the moment, which I think it's ridiculous. Of course, there is. I think the issue is something that's not seen serious enough by the government.'</i> (P14) <i>'I find it very alarming if I'm honest ... given those statistics, I'm very surprised at the lack of action on the part of governments on the part of individuals.'</i> (P19)
<b>Awareness and education:</b> The video serves as an educational tool, providing viewers with valuable information about topics such as CO2 emissions, global warming and sustainability. It highlights the importance of understanding these issues and their real-world implications.	
<b>Surprise and eye-opening moments:</b> Many viewers express surprise and find certain aspects of the video eye-opening, such as the impact of different modes of transport on CO2 emissions, the inefficiencies of certain travel choices and the severity of the environmental challenges we face.	
<b>Perspective shift and behaviour change:</b> The information presented in the video leads to a shift in perspective for some viewers, prompting them to reconsider their attitudes and behaviours towards transport and sustainability. It encourages them to think more critically about their choices and their impact on the environment.	
<b>Call for action and responsibility:</b> The video sparks a call for action and a sense of responsibility amongst viewers. It emphasizes the need for individuals, governments and society to take concrete steps towards reducing CO2 emissions.	

options. The video not only increased participants' knowledge about sustainable transport but also had a positive impact on their attitudes and behaviours towards it. Some of the feedback from participants is presented in Table 7. The findings from the participants' feedback highlight the effectiveness of using educational videos to raise awareness and promote sustainable transport options. On average, the participants gave a rating of

4.27 (SD = 0.58) to the video on a scale from 0 to 5 (0 being not effective and 5 being very highly effective).

#### 4.4. Knowledge assessment game

Predominantly all participants found that games were significantly efficient in increasing their knowledge and awareness about sustainable transport options. We have also observed that

**Table 7.** Examples of participants' feedback on the impact of the video

ID	Impact on behaviour and or attitude after watching the video
P3	<i>Now I will take the big car for my family rather taking two cars, as I learn from the video. I am still surprised.</i>
P6	<i>It was informative, I was quite shocked; I wasn't aware how significant the difference was, especially aeroplanes. I considered it to be a lot lower when I thought about per person, but actually it was quite a lot more than I thought. It made me reconsider it there. And the car share.</i>
P10	<i>After watching the videos of the risks and how the carbon emission getting higher every time you could say everyday every hour and how it's affecting our planet. If you think if I'm keep using car and not considering environment, it is very dangerous for our kids, for the next generations. So, everyone's has responsibility to keep their planet safe and trying to reduce the carbon emissions, especially from travelling because it's very, very high.</i>
P14	<i>I do carpool in the mornings. I've done that for ages. So, I'd love to be public transport, but again, links aren't good between the towns and cities. Absolutely dreadful as, even the way that the buses.</i>
P18	<i>It would, but it's the cost and convenience. If it were cost, then I would go by train. Cause I do care about the environment. I've recycled everything I can, and I do care.</i>
P22	<i>That was interesting to sort of see, a plane, you can get that much, many more people in it, but it's still high in its emissions. And then you've got the train, you can get lots of people in it and it's low on the emissions. So yeah, it does make you think actually.</i>
P23	<i>I gained more knowledge. This video definitely got me thinking. This also important to talk to other people who are not aware.</i>
P30	<i>Car share, I drive to work every day on my own and I would say most cars that I pass of only got one person in them. Definitely, there are other people that work here that live in the same place. Say you know that would be an easy share. Motorbike I was surprised, my partner got a motorbike.</i>

participants enjoyed the video, engaged with the content and had some behavioural intention impact. However, when they played the game, knowledge and awareness were further enhanced and retained at a higher level. Details about the participants' comments on the two interactive games (Section 3.3.2) can be found in Table 8. All participants had positive experience with both games, but some individuals found the second game to be more enjoyable. This was true even for those who had initially struggled or perceived the games as challenging. Interestingly, some participants were able to acquire knowledge and develop awareness about transport sustainability through the gameplay stage of the game. This included learning about topics such as the high emissions of planes and the carbon efficiency of sharing transport. These insights were not obtained while they were watching the video. The majority of participants gained knowledge after they have played the games. In this study educational games have been shown to be engaging and effective in facilitating the learning process, leading to improved knowledge and awareness regarding sustainable transport choices.

As with knowledge and awareness, participants' attitudes and behavioural intentions were also positively influenced more by the games than by the video. Participants reported stronger willingness to consider sustainable transport options and expressed a desire to make changes in their commuting behaviours. Furthermore, they considered changing their vehicle to a more sustainable type and changing to public transport or carpooling. They also expressed an increased understanding of the environmental and social benefits of sustainable transport. Most participants upheld their intention to explore the option to share a car. Participants were very motivated to use trains and other public transport as a mode of transport for both long and short distances, as they had identified to be more sustainable compared to cars or planes. However, the concerns remain about cost, time, reliability and accessibility of public transport options. Also, government policy and transport network infrastructure, especially in towns and rural areas, were identified as important factors that could further support the adoption of sustainable transport options.

Some of the participants' comments related to changes in behavioural intentions are presented in Table 9. Accordingly, the educational games used in the study were found to be effective in improving knowledge and awareness of sustainable transport choices after watching the video. On average, the participants assigned a rating of 4.77 (SD = 0.43) to the games on a scale from

0 to 5 (0 being not effective and 5 being very highly effective). Participants rated the games either equal or higher than the video. The high ratings suggested that participants highly valued the games as tools for learning, promoting sustainable transport, fostering positive attitudes, behaviour change and enjoyment.

#### 4.5. Post-intervention travel planning

All 10 participants who previously had low sustainable choice for their primary transport options have switched to more sustainable options. However, none of the three individuals who had a medium sustainable choice have altered their transport preference. Two participants who had a medium sustainable choice took sustainability into account when choosing their primary transport but did not make any changes based on cost considerations. All participants considered sustainability in their post-intervention primary transport choice; on average they considered an average of 3.47 (SD = 1.57) on a scale from 0 to 5 (0 being not considered and 5 being very highly considered). Details are shown in Table 10.

Participants who considered sustainability in their post-intervention primary transport choice and changed on average they considered sustainability an average of 4.2; on the other hand, participants who did not change on average they considered sustainability an average of 2.00.

When it comes to secondary transport, amongst the 12 participants who previously favoured highly sustainable choice, four individuals have transitioned to walking whenever feasible. The remaining participants prioritized sustainability when making their post-intervention plans. One out of five participants who had initially favoured a medium sustainable choice made changes to their transport choices. However, the other four participants who did not change their transport choice, still considered more sustainable options but ultimately stuck with their initial choice due to convenience and the practicality of their primary transport choice. Eight out of 11 participants with a low sustainable choice considered sustainability and changed their secondary transport choice. However, three participants did not make any changes to their transport choices. One out of the three participants who did not change their secondary transport choice did so for reasons of convenience and comfort and also stated that they were highly satisfied with their primary transport's sustainability considerations. The other two participants did not prioritize sustainability when choosing their secondary mode of transport. They were more concerned with convenience, comfort and control as the

**Table 8.** Theme identified from participants' comments on the games with example quotes

Theme	Examples of Comments
<b>Effectiveness of interactive learning:</b> The games help to solidify information and make it more memorable and provide the opportunity to test knowledge in a fun and engaging way, which facilitates deeper learning and understanding.	<i>'I'm glad I feel better informed now. A good test I think of what are gleaned. As a game a nice kind of fun interactive way of maybe making people more mindful of the different modes of transport.'</i> (P19) <i>'I like the games. You think you know and then something throws to you, you realize that it's not established in you. I think the game's very best. It just got you to stop and just think about each particular mode of transport.'</i> (P17) <i>'I love a little memory game. It shows that I retain the knowledge that was told to me. Even if you don't do it right the first time you learn it again.'</i> (P10). <i>'It was interesting. I think the original card sorting I did; I didn't have a clue. And then once I obviously had watched the videos and had some more information, it definitely gave me a more informed choice. I think I'm surprised at how much I retained. I thought I was my memory would be much worse or less specific, but clearly, I've registered.'</i> (P13) <i>'I think it's increased my knowledge more to be honest. I've been able to, in a short amount time, to memorize that, especially the numbers and order. That was quite tricky testing against the different bits of transport. I feel like that allows me to memorize that a lot more, more rather than just having a sentence.'</i> (P21) <i>'It's a good approach to learn, and I think it'll be pretty cemented now. And now subconsciously I think that will have an effect on my decisions in the future. Now I know the impact is. I still can't believe motorbikes are as bad as they are.'</i> (P6) <i>'Eye opening for me. I'm now thinking my lack of knowledge is something that I need to brush up on, and so it's definitely got me thinking. Car sharing was a surprise. I wasn't aware about that. As you probably saw from the first exercise, how high I thought car share would be but by the fact of sharing.'</i> (P23) <i>'It confirms and consolidates sort of that knowledge into something practical that you could other than just walking away with that knowledge, you've had to do something with it makes it more meaningful, definitely.'</i> (P22)
<b>Reflection, retention on personal knowledge and understanding:</b> The activities aid in retaining information, deepening the understanding of the topic and prompting individuals to reflect on their own knowledge and understanding of environmental issues that they have previously been unaware or misinformed, highlighting the importance of ongoing education and learning.	
<b>Change in attitude and behaviour:</b> The games make participants consider more sustainable options and more mindful of their impact on the environment.	
<b>Surprise and eye-opening moments:</b> The games reveal unexpected insights, prompting individuals to reconsider their assumptions and broaden their understanding of sustainability.	
<b>Appreciation for practical application:</b> The activities allow participants to apply their knowledge in a practical context.	

reasons for their choice. Two participants chose car share and van share as their primary transport, eliminating the need for secondary transport. However, the average sustainability consideration for post-intervention secondary transport choices amongst the participants is 3.53 (SD = 1.55) on a scale of 0–5 (0 being not considered and 5 being very highly considered).

Participants expressed a desire to incorporate sustainable practices into their daily lives whenever feasible. Certain participants are willing to increase their walking distance and are open to sacrificing other transport motivational factors, except for cost. The majority of participants expressed willingness to engage in walking as their mode of transport, taking into consideration factors such as distance and personal energy levels. One of the participants maintained 'It's cheaper to fly to Scotland because I went to Scotland recently. The flight was ... something like about 45 pounds return and to go by train, it was like over 100 pounds. Yeah, it was ridiculous. So, you know, its cost is the factor really. I want to go by train, but the cost is too high.' However, all participants who have chosen flight in their pre-intervention planning expressed similar thoughts, such as P4 stating 'I definitely put plane off a table. I was quite shocked by how high the plane was. I didn't realize plane that high. After watching the videos and playing the games, I would use a train more'. Two participants called their initial choice a 'practical choice' when they were not considering sustainability, they are in the low sustainable choice group who didn't change their choice.

After acquiring more knowledge, participants displayed willingness to deviate from their previous habitual or experience-based selection, reconsidering or adapting a new motivation-based selection. For example: P5 'Still cost. Now, I considered the environmental impacts more because it got me thinking about the.'; P10

'I want to get there fast. But now, after seeing how bad it is for the environment, it makes you think. I want to get there more environmentally healthy. I want to get there in a more sustainable way.'; P11 'First one Accessibility to be honest and second one, again, accessibility and sustainability.'; P16 'Now I have the knowledge, my default mode needs to change, 100%'; P18 'I have been to Scotland many times, I always fly, it's cheap and convenient. Next time I will try to go by train, definitely. The emission differences got me thinking.'; P19 'My thinking process has changed because I'm this has obviously made me more mindful of the impact. All of the transport method I choose and, and probably initially I was thinking, I need to change. The impact from the point of view of CO2 emissions of air travel. I would rule it out straight away.' and 'Probably I have been convenience if I'm honest, but having to actually plan ahead, allow more time to find better options.'; P20 'I think possibly the reason that my travel choice wasn't sustainable because thinking of it based on the way I prefer to travel. But I just love trains. It's just more relaxing. They make it hard to use a train. They are so expensive.'; P25 'Now, I will be open to share, if I could trust them and they wanted to go on the same journey. Even if it meant collecting them on the route. I can do this.'; P30 'So actually, having that knowledge now would make me think before.'

#### 4.6. COVID impact on travel

According to the feedback from 22 participants out of 30, their travel behaviour, frequency of travel and transport choices remained unaffected by COVID-19. For some participants the frequency of travel changes before and after COVID-19 because of moving to a new location, changing jobs, change of job role, change of circumstance and Brexit. The travel behaviour, frequency of travelling or transport choices of eight participants were impacted due to COVID-19. Out of the eight participants,

**Table 9.** Themes identified in participants' comments on the impact of the games

Theme	Example quotes
<b>Environmental consciousness:</b> Participants demonstrate a heightened awareness of environmental impact, expressing preferences for more environmentally friendly options.	'If it's a case of coaches over train, both being the same price, I would pick the option this a little bit environmentally friendly, even if it's a little bit longer, like an extra hour journey.' (P1)
<b>Cost considerations:</b> Cost emerges as a significant factor influencing transport choices, with individuals willing to choose environmentally friendly options if they are economically viable.	'Electric car, I would still purchase over diesel or petrol engine. It's down to cost, down to because they're just too expensive to buy. Similar to the train, if that was cheap, I'll take the risk of potentially being on an unreliable service. The cost is just the biggest factor.' (P2)
<b>Surprise and revelation:</b> Many express surprises at the environmental impact of certain modes of transport, indicating a shift in understanding and perception.	'I am shocked by plane. When you're sharing a car is the carbon emission gets very low. Even then motorbike, I was surprised when I saw that motorbikes have that high carbon emissions.' (P9)
<b>Preference for sustainable options:</b> There is a stated intention to prioritize more sustainable transport methods over default choices, indicating a willingness to change behaviour based on newfound knowledge.	'I definitely would change my mind. I think one of the main things is the amount of people in my car. Like, it definitely makes me more enthusiastic to carpool. After seeing the difference, it would be more of exoneration in my mind to change that. It has been more in my mind.' (P7)
<b>Desire for change and action:</b> Participants express a desire to change their transport habits and actively seek more environmentally friendly alternatives. Priorities regarding transport choices are reevaluated, with an emphasis on sustainability and environmental impact over convenience or habit.	'I always choose the direct routes quickly as everyone does it in there. No one's going to look at their carbon. Now I'm going to do it because it's important... Wanted to change my mode of transport to work.' (P15)
<b>Knowledge acquisition and reflection:</b> The experience leads to increased knowledge about different modes of transport and their environmental impact, prompting reflection on personal habits and choices.	'I am living in the village. There is no bus coming here. So, I was thinking there are two people that live in the village that I live in, we've all three of us work here. Maybe we can share.' (P20)
<b>Scepticism and realism:</b> Despite the desire for change, practical constraints such as availability of public transport in certain areas are acknowledged, highlighting the need for feasible alternatives.	'I had never previously considered car sharing or van sharing in my case. As something that perhaps could be socially constructed somehow. It's not an idea that had occurred to me or, an awareness that I had. I also wasn't aware of quite how much worse flying was. I would never even think about a domestic flight. It has made me think more carefully about international, long flights and even short-haul flights.' (P25)
	'I could come to work by public transport, and if we had good public transport. Now I like to come by public transport, but not possible.' (P19)
	'With the knowledge I can change my transport easily. Surprised by car share. The train should be cheaper and reliable. I have bad experience with train. Reliability of train is poor.' (P23)
	'I want to try to do more like walk to work rather than drive to work. But I'm not going to do every day, sometimes it's not possible.' (P26)

four travelled less frequently after COVID-19. The reasons given were working from home, taking less overseas trips or holidays, using more technology to communicate with friends and family, still felt uncomfortable with travelling and technological change in communication. Two participants reported that their travel behaviour changed but not frequency as one of them now prefers to walk more after a habitual change happened during COVID-19 and another participant uses less public transport as he or she still feels uncomfortable to travel by public transport. Two other participants reported that they now travel more frequently; one participant said, 'I have walked a lot during the pandemic, but now I do not want to walk and travel more' and the other participant stated 'I travel more because of COVID. I think there's an element of living life to the full after COVID.' The participant feedback revealed that COVID-19 had varying impacts on travel behaviour, frequency of travel and transport choices.

#### 4.7. Low sustainable choice group

The low sustainable choice group, who didn't change their transport choice irrespective of the intervention, may need extra knowledge or/and motivation to change behaviour; we referred to them as the resistance-to-change group consisting of three participants. This group may also need targeted interventions that address their specific barriers and provide them with the necessary resources to make sustainable choices.

Given the small group size, it is not possible to generalize a pattern on who will need extra attention to change their behaviour;

however, we have discussed a few possible early indications of the behaviour. The three participants in the resistance-to-change group were female; however, we are not able to draw any definitive conclusions or generalizations on gender-related factors based on the limited sample size. However, the focus on differences in men's and women's travel patterns has been a characteristic in many discussions (Pourhashem et al., 2022). The concept of gender-specific mobility pertains to the differences in how male and female travellers behave, which may include: women use slower transport modes such as public transport and walking more frequently than men; they travel shorter distances; they have more intricate travel patterns; women tend to travel in the company of children or other dependents with special needs more frequently (Frändberg and Vilhelmson, 2011; European Commission, 2014; Tilley and Houston, 2016).

We found that the resistance-to-change group had lower levels of environmental knowledge and awareness compared to the other participants. For the pre-intervention knowledge of CO<sub>2</sub> emission for transport mode, this group had the average accuracy of 16.67% as compared with the overall accuracy of 21.67%.

Participants in the resistance-to-change group showed lower levels of sustainability in their transport choices and consideration compared to the other participants. Resistance-to-change group had notably lower consideration in terms of both primary and secondary transport, they have rated their consideration for primary transport with 2 and for secondary transport with 0.5.



**Table 10.** Pre-and post-intervention transport choices

Participant	Pre-intervention transport choice	Post-intervention transport choice	Sustainable choice	Changed
P1	Train	Train	High	N/A
P2	Train	Train	High	N/A
P3	Bus	Bus	Medium	No
P4	Train	Train	High	N/A
P5	Bus	Bus	Medium	No
P6	Car	Car share	Low	Yes
P7	Train	Train	High	N/A
P8	Train	Train	High	N/A
P9	Train	Train	High	N/A
P10	Bus	Bus	Medium	No
P11	Train	Train	High	N/A
P12	Train	Train	High	N/A
P13	Train	Train	High	N/A
P14	Train	Train	High	N/A
P15	Flight	Train	Low	Yes
P16	Train	Train	High	N/A
P17	Train	Train	High	N/A
P18	Car	Train	Low	Yes
P19	Flight	Train	Low	Yes
P20	Train	Train	High	N/A
P21	Flight	Train	Low	Yes
P22	Fight	Train	Low	Yes
P23	Flight	Train	Low	Yes
P24	Train	Train	High	N/A
P25	Van	Van Share	Low	Yes
P26	Train	Train	High	N/A
P27	Train	Train	High	N/A
P28	Flight	Train	Low	Yes
P29	Train	Train	High	N/A
P30	Flight	Train	Low	Yes

These findings highlight the need for targeted interventions and additional information to improve environmental knowledge, awareness and sustainable transport choices amongst the resistance-to-change group. It is crucial to conduct further research to gain a deeper understanding of the specific factors influencing this specific group's resistance to sustainable behaviour change.

## 5. DISCUSSION

In this section, we first revisit the three RQs (Section 1: Introduction), addressing them based on the empirical results obtained. Then we discuss the limitations and future work.

### 5.1. RQ1: What is the level of knowledge about carbon emissions of transport options amongst travellers?

Researchers (Murad and Law, 2023) found that ABTs had a lack of knowledge and understanding regarding sustainability and carbon emissions related to transport. Walsh and Dodds (2022) highlighted in their research 'Although climate change and the need for more sustainable development has become a regular discussion in many people's lives, this topic may still not be well understood.' (p.6). Therefore, it was crucial to ascertain whether there was a lack of understanding amongst travellers in general.

In this study, participants from diverse backgrounds and professions were recruited for the purpose of gaining insight into their awareness of the carbon emissions associated with various transport choices. The participants' knowledge about carbon emissions of different transport modes was assessed and the

findings revealed that there was a general lack of knowledge amongst travellers about carbon emissions of different transport modes. The level of knowledge about carbon emissions of transport options amongst travellers is generally low, with an overall accuracy rate of only 21.67%. This indicates the need for education and initiatives to increase awareness and knowledge amongst travellers about the environmental impact of different transport modes and the importance of choosing sustainable transport choices. This discovery also implies the importance of comprehending participants' knowledge and understanding before designing any behaviour or attitude change interventions.

### 5.2. RQ2: How can the knowledge about carbon emissions of transport options influence travellers' decision-making process and their willingness to choose sustainable transport options?

Researchers (Murad and Law, 2023) found that ABTs demonstrated limited motivation to explore sustainable modes of transport due to a lack of knowledge. Their study revealed the key factors behind transport choices and suggested target behaviour can be set according to ability. They have also indicated that travellers were keen about transport time, convenience and cost. These factors were relatively important to consider different modes of transport. The research also highlighted that the target new behaviour should not require additional physical effort or high cognitive load, not against the social norm, and should be simple behaviour they familiar with.

In this study, we have focused on examining the effects of knowledge on participants' engagement levels and attitudes towards sustainability. The results revealed that the knowledge

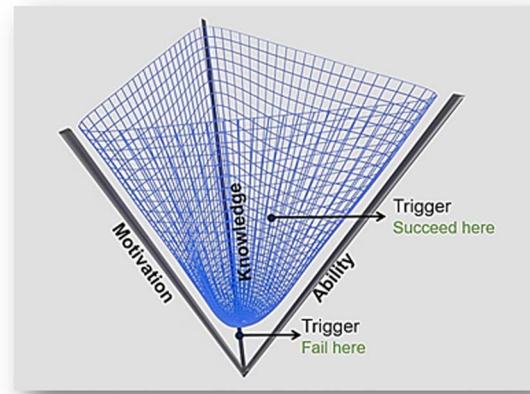
had a positive effect on engagement levels and attitudes towards sustainability amongst participants. Prior to the intervention, none of the participants had considered sustainability when making their transport choice. However, after gaining knowledge as a result of exposing to the intervention, the participants demonstrated a notable rise in their consideration to sustainability when making both primary and secondary transport decisions, with an average rating of 3.5 out of 5. Furthermore, a considerable proportion of the participants opted for a more sustainable mode of transport. Overall, this study suggests that knowledge plays a crucial role in influencing individuals' engagement and attitudes towards sustainability. This implies that providing individuals with sufficient environmental knowledge and education can lead to positive changes in their attitudes and engagement towards sustainable transport choices. This study suggests that knowledge plays a crucial role in driving individuals' intention to choose sustainable transport options. These findings emphasize the importance of education and awareness in promoting sustainable behaviour.

To effectively promote sustainable transport choices, it's essential that the information provided is factual, reliable and based on credible sources. The presentation of this information should be both clear and engaging. Active interaction with learning materials is highly recommended, as it helps people retain and apply the information to real-life scenarios. Incorporating gamification elements—such as rewards, challenges and social reinforcement programmes—can further enhance the learning process. In this study, we have integrated these strategies into our informational videos and gamified quizzes. However, there is still potential for improvement based on user feedback.

### 5.3. RQ3: What are the theoretical and practical implications for promoting sustainable behaviour change?

Based on the findings, we argue that motivation, ability and triggers can be sufficient for a simple behaviour change. However, for pro-environmental behaviour change, those elements alone cannot cause a new behaviour. Knowledge should be added to pro-environmental behaviour change. The knowledge must be reliable, accurate and presented in such a way that travellers can easily understand it. Therefore, we propose the **Inverted Pyramid model** for sustainable behaviour change (Fig. 7), as inspired by Fogg's work (Fogg, 2003, 2009, 2022).

Knowledge has been added to make it more specific to the need for pro-environmental behaviour change. This new model suggests that individuals must have non-zero level of motivation, ability and knowledge to have a successful trigger similar to Fogg's behaviour model, which suggests non-zero level of motivation and ability. The Inverted Pyramid model for sustainable behaviour change can have a trade-off relationship motivation, ability and knowledge, yet all of them must be above non-zero level. In case of very low levels of motivation, ability and knowledge, it is essential to concentrate on boosting those before implementing triggers. If triggers were used for the early stage when motivation, ability and knowledge were very low, they failed; the same triggers might not have full potential when individuals achieve a minimum level of motivation, ability and knowledge. Minimum motivation can be measured when individuals think proposed change will be interesting; for the ability, new target behaviour shouldn't be too different from the present behaviour; and finally, they should have knowledge about their consumption and what difference new behaviour can make. Individuals might have misconceptions about their ability in the area of sustainable behaviour change.



**Figure 7.** Inverted Pyramid model for sustainable behaviour change (adapted from Fogg (2022)).

This needs to be considered, and in some cases providing realistic information can be useful.

Overall, implications can be inferred from the above reflections to inform policymakers and practitioners how to promote sustainable transport choices. Specifically, a holistic approach is essential, addressing motivation, ability and knowledge. For example, a public awareness campaign can educate on environmental impacts, highlight the convenience of alternatives and promote the social benefits of sustainable behaviours. Early interventions should focus on gradually building these factors, such as offering free public transport trials paired with educational workshops in car-dependent areas. Gradual transitions, like encouraging carpooling, help ease individuals into sustainable habits. Knowledge is critical, and tools like an educational app can provide insights into the benefits of alternative transport options. Timing of triggers, such as incentives during a 'Green Commute Week', should align with increased readiness. Tailored interventions, such as promoting e-bikes to long-distance commuters, ensure relevance. Continuous feedback through surveys or apps allows for adaptation and refinement of strategies, ensuring sustained behaviour change and effective adoption of sustainable transport.

### 5.4. Limitations and future work

Our work has some limitations. First, the small size of the sample may affect the generalizability of the study's findings and constrains comprehensive quantitative analysis. In addition, there could be possible links between gender and different age group regarding sustainable behaviour or attitude change. These possible links have not been explored due to the small sample size. Researchers have identified that gender disparities affect the preferences, perceived value and travel behaviour of individuals (Pourhashem et al., 2022). Therefore, it is important for future research to consider the potential influence of gender and age in the study. However, the results provide valuable insights into the general lack of knowledge amongst travellers about carbon emissions and highlight the need for education and initiatives to increase awareness and knowledge in this area for successful behaviour or attitude change intervention. Second, the behavioural intention change, not actual behaviour change observed as participants may not actually follow through on their stated intentions in real-life situations. Future research

is needed to measure the effectiveness of educational initiatives in improving knowledge and attitudes towards sustainable transport choices, as well as the impact on actual behaviour change and carbon emissions reduction. Therefore, for our future work, we will focus on developing an effective persuasive technology such as mobile app or web system to incorporate the 'Inverted Pyramid model' for persuasive interventions to educate and engage travellers about carbon emissions and sustainable transport choices.

## 6. CONCLUSION

Motivated by the intriguing phenomenon that generally people are reluctant to change travel choices irrespective of increasing awareness of climate change, we conducted the empirical study with 30 participants of various backgrounds, using a combination of different methods and tools. Results were primarily derived from thematic analysis and descriptive statistics.

Overall, our research study identified a common lack of awareness amongst travellers regarding the carbon emissions associated with different modes of transport. It demonstrates the crucial role of knowledge and education in promoting sustainable behaviour and attitudes towards transport. The findings of our study suggest that sufficient environmental knowledge and education can lead to positive changes in individuals' attitudes and engagement towards sustainable transport choices. To address the challenge of developing an effective intervention for pro-environment travel choices, we propose using the 'Inverted Pyramid model' to inform the design of a technology-supported intervention as a mobile app. This new model suggests that individuals must have non-zero level of motivation, ability and knowledge to have a successful trigger. Additionally, the study highlights the potential of using persuasive strategies in design to influence user behaviour towards more sustainable practises. While our study resulted in the relevant insight that knowledge enhancement can lead to changes in behavioural intention, it is important to highlight that not actual behaviour changes have been observed as participants may not necessarily follow through on their stated intentions in real-life situations. Our future work should explore this critical issue.

## References

- Ahmed, S., Adnan, M., Janssens, D. and Wets, G. (2020) A personalized mobility based intervention to promote pro-environmental travel behavior. *Sustain. Cities Soc.*, **62**, 102397. <https://doi.org/10.1016/j.scs.2020.102397>.
- Ajzen, I. (1991) The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.*, **50**, 179–211.
- Ali, B. A., Abdulsalam, H. M., Almadani, S. and Manuel, P. (2023) A study of a hybrid Fogg-Hook based social media addictive algorithm from the perspective of Kuwait society. *J. Eng. Res.* <https://doi.org/10.1016/j.jer.2023.09.008>.
- Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J. and Mentzas, G. (2018) Persuasive technologies for sustainable mobility: state of the art and emerging trends. *Sustain. For.*, **10**, 2128. <https://doi.org/10.3390/su10072128>.
- Andersson, A., Winslott Hiselius, L. and Adell, E. (2018) Promoting sustainable travel behaviour through the use of smart-phone applications: a review and development of a conceptual model. *Travel Behav. Soc.*, **11**, 52–61. <https://doi.org/10.1016/j.tbs.2017.12.008>.
- Aronson, J. (1995) A pragmatic view of thematic analysis. *Qual. Rep.*, **2**, 1–3.
- Bamberg, S., Fujii, S., Friman, M. and Gärling, T. (2011) Behaviour theory and soft transport policy measures. *Transp. Policy*, [online], **18**, 228–235. <https://doi.org/10.1016/j.tranpol.2010.08.006>.
- Bărbuceanu, C. D. (2020) Visual teaching – using digitalised material to engage ESP students. *Revista de științe Politice. Revue des Sciences Politiques*, **online**, 36–44.
- Bartosova, M., Svetlak, M., Kukletova, M., Borilova Linhartova, P., Dusek, L. and Izakovicova Holla, L. (2019) Emotional stimuli candidates for behavioural intervention in the prevention of early childhood caries: a pilot study. *BMC Oral Health*, **19**, 1–8. <https://doi.org/10.1186/s12903-019-0718-4>.
- Bertolini, L. (2005) Sustainable urban mobility, an evolutionary approach. *Eur. Spat. Res. Policy*, **12**, 109.
- Boyatzis, R. E. (1998) *Transforming qualitative information: thematic analysis and code development*. Sage Publications, Inc., Thousand Oaks.
- Bradley, M. M. and Lang, P. J. (1994) Measuring emotion: the self-assessment manikin and the semantic differential. *J. Behav. Ther. Exp. Psychiatry*, **25**, 49–59. [https://doi.org/10.1016/0005-7916\(94\)90063-9](https://doi.org/10.1016/0005-7916(94)90063-9).
- Brög, W., Erl, E., Ker, I., Ryle, J. and Wall, R. (2009) Evaluation of voluntary travel behaviour change: experiences from three continents. *Transp. Policy*, **16**, 281–292. <https://doi.org/10.1016/j.tranpol.2009.10.003>.
- Brown, D. (2010) Eight principles of information architecture. *Bull. Am. Soc. Inf. Sci. Technol.*, **36**, 30–34. <https://doi.org/10.1002/bult.2010.1720360609>.
- Chatterjee, K. (2009) A comparative evaluation of large-scale personal travel planning projects in England. *Transp. Policy*, **16**, 293–305. <https://doi.org/10.1016/j.tranpol.2009.10.004>.
- Davies, N. (2012) What are the ingredients of successful travel behavioural change campaigns? *Transp. Policy*, **24**, 19–29. <https://doi.org/10.1016/j.tranpol.2012.06.017>.
- Davis, R., Campbell, R., Hildon, Z., Hobbs, L. and Michie, S. (2015) Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychol. Rev.*, **9**, 323–344. <https://doi.org/10.1080/17437199.2014.941722>.
- Department for Transport, UK (2023) *Transport and environment statistics: 2023*. UK Government, London. Available at: <https://www.gov.uk/government/statistics/transport-and-environment-statistics-2023/transport-and-environment-statistics-2023>.
- European Commission, Directorate-General for Mobility and Transport (2014) *She Moves: Women's Issues in Transportation*. Publications Office, Luxembourg, Luxembourg.
- Fogg, B. J. (2003) *Persuasive Technology: Using Computers to Change What We Think and Do*. Morgan Kaufman, San Francisco.
- Fogg, B. J. (2009) A Behavior Model for Persuasive Design. In *Proceedings of the 4th international Conference on Persuasive Technology*, pp. 1–7. ACM, New York, United States. Claremont California, 26–29 April 2009.
- Fogg, B. J. (2022) *Fogg Behavior Model*. Des. Lab., Stanford Univ., Stanford, CA, USA, Tech. Rep. <https://behaviormodel.org> (accessed on 18/2/2024).
- Foster, D., Lawson, S., Blythe, M. and Cairns, P. (2010, October) Watsup? Motivating Reductions in Domestic Energy Consumption Using Social Networks. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, pp. 178–187, Reykjavik, Iceland, October 16 - 20, 2010. ACM, New York, USA.

- Frändberg, L. and Vilhelmson, B. (2011) More or less travel: personal mobility trends in the Swedish population focusing gender and cohort. *J. Transp. Geogr.*, **19**, 1235–1244.
- Frøehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B. and Landay, J. A. (2009) UbiGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 1043–1052. Boston MA USA April 4 - 9, 2009. ACM, New York, USA.
- Frøehlich, J., Findlater, L. and Landay, J. (2010) The Design of Eco-Feedback Technology. In *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10*. <https://doi.org/10.1145/1753326.1753629>. Atlanta Georgia USA April 10 - 15, 2010. ACM, New York, USA.
- García-Garcés, P., Ruiz, T. and Habib, K. M. N. (2015) Effect of travel behaviour change programmes on time allocated to driving. *Transportmetrica A Transp. Sci.*, **12**, 1–19. <https://doi.org/10.1080/23249935.2015.1074953>.
- Gilakjani, A. P. (2012) Visual, auditory, kinaesthetic learning styles and their impacts on English language teaching. *J. Stud. Educ.*, **2**, 104. <https://doi.org/10.5296/jse.v2i1.1007>.
- Glasgow City Council (2023) *Glasgow Travel Behaviour Change Strategy*. UK Government, Glasgow. Available at: <https://www.glasgow.gov.uk/CouncillorsandCommittees/viewSelectedDocument.asp?c=P62AFQDNZ3DXZLT1NT>.
- Graham-Rowe, E., Skippon, S., Gardner, B. and Abraham, C. (2011) Can we reduce car use and, if so, how? A review of available evidence. *Transp. Res. A Policy Pract.*, **45**, 401–418. <https://doi.org/10.1016/j.trra.2011.02.001>.
- Grilli, G. and Curtis, J. (2021) Encouraging pro-environmental behaviours: a review of methods and approaches. *Renew. Sust. Energ. Rev.*, **135**, 110039. <https://doi.org/10.1016/j.rser.2020.110039>.
- Gupta, T., Kar, N., Mishra W. and Loudon, G. (2021) *Persuasive Design for Sustainable Mobility*. Virtual Event India November 19 - 21, 2021. ACM, New York, SA. <https://doi.org/10.1145/3506469.3506490>.
- Harries, T., Eslambolchilar, P., Stride, C., Rettie, R. and Walton, S. (2013) Walking in the Wild—Using an Always-on Smartphone Application to Increase Physical Activity. In Kotzé, P., Marsden, G., Lindgaard, G., Wesson, J., Winckler, M. (eds), *Human-Computer Interaction—INTERACT 2013: 14th IFIP TC 13 International Conference, Proceedings, Part IV 14*, pp. 19–36. Springer, Berlin Heidelberg.
- Huang, B., Thomas, T., Groenewolt, B., Claasen, Y. and Berkum, E. (2021) Effectiveness of incentives offered by mobile phone app to encourage cycling: a long-term study. *IET Intell. Transp. Syst.*, **15**, 406–422. <https://doi.org/10.1049/itr2.12034>.
- IEA (2023a) *Tracking Clean Energy Progress 2023*. IEA, Paris. <https://www.iea.org/reports/tracking-clean-energy-progress-2023>, Licence: CC BY 4.0.
- IEA (2023b) *Transport - Energy System*. IEA. Licence: CC BY4.0. <https://www.iea.org/energy-system/transport>.
- Klaniecki, K., Wuropulos, K. and Hager, C.P. (2018) Behaviour Change for Sustainable Development. In *Encyclopedia of Sustainability in Higher Education*, pp. 1–10. Springer International Publishing, Cham. [https://doi.org/10.1007/978-3-319-63951-2\\_161-1](https://doi.org/10.1007/978-3-319-63951-2_161-1).
- Lilley, D. (2009) Design for sustainable behaviour: strategies and perceptions. *Des. Stud.*, **30**, 704–720.
- Lockton, D., Harrison, D. and Stanton, N. A. (2010) The design with intent method: a design tool for influencing user behaviour. *Appl. Ergon.*, **41**, 382–392. <https://doi.org/10.1016/j.apergo.2009.09.001>.
- Ludden, G. D. S. and Hekkert, P. (2014) Design for Healthy Behavior. Design Interventions and Stages of Change. In Salamanca, J., Desmet, P., Burbano, A., Ludden, G., Maya, J. (eds), *Proceedings of the Colors of Care: The 9th International Conference on Design & Emotion*. Bogotá, October 6–10, 2014. Ediciones Uniandes, Bogotá, 2014. ISBN: 978-958-774-070-7.
- MacInnes, S., Grün, B. and Dolnicar, S. (2022) Habit drives sustainable tourist behaviour. *Ann. Tour. Res.*, **92**, 103329. <https://doi.org/10.1016/j.annals.2021.103329>.
- Möser, G. and Bamberg, S. (2008) The effectiveness of soft transport policy measures: a critical assessment and meta-analysis of empirical evidence. *J. Environ. Psychol.*, **28**, 10–26. <https://doi.org/10.1016/j.jenvp.2007.09.001>.
- Murad, S. and Law, E. (2023) An Exploratory Study on Sustainable Academic Business Travel: Implications for Technological Design for Behaviour Change. In *Proceedings of 36th International BCS Human Computer Interaction Conference*. <https://doi.org/10.14236/ewic/BCSHCI2023.4>.
- Murad, S., Bradley, M., Kodagoda, N., Barnard, Y. and Lloyd, A. (2012) 2012, Using Task Analysis to Explore Older Novice Participants' Experiences with a Handheld Touchscreen Device. In Anderson, M. (ed), *Contemporary Ergonomics and Human Factors 2012*, pp. 57–64. CRC Press, Boca Raton.
- Nacke, L. E., Nacke, A. and Lindley, C. A. (2009) Brain training for silver gamers: effects of age and game form on effectiveness, efficiency, self-assessment, and gameplay experience. *CyberPsychol. Behav.*, **12**, 493–499. <https://doi.org/10.1089/cpb.2009.0013>.
- NASA Earth Observatory (2023) 2022 Tied for Fifth Warmest Year on Record. NASA, USA. Available at: <https://earthobservatory.nasa.gov/images/150828/2022-tied-for-fifth-warmest-year-on-record>.
- Niedderer, K. (2022) Design for behaviour change: taking the long view fast. In Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds), *DRS2022: Bilbao*, 25 June - 3 July, Bilbao, Spain. <https://doi.org/10.21606/drs.2022.1075>.
- Niedderer, K. et al. (2014) *Creating Sustainable Innovation Through Design for Behaviour Change: Full Project Report*.
- Niedderer, K., Clune, S. and Ludden, G. (2017) *Design for Behaviour Change*. Routledge, London.
- OECD (2017) *Behavioral Insights and Public Policy: Lessons from Around the World*. OECD Publishing, Paris.
- Okraszewska, R., Romanowska, A., Laetsch, D. C., Gobis, A., Reisch, L. A., Kamphuis, C. B. et al. (2024) Interventions reducing car usage: systematic review and meta-analysis. *Transp. Res. Part D: Transp. Environ.*, **131**, 104217.
- Parajuly, K., Fitzpatrick, C., Muldoon, O. and Kuehr, R. (2020) Behavioral change for the circular economy: a review with focus on electronic waste management in the EU. *Resour. Conserv. Recycl. X*, [online], **6**, 100035. <https://doi.org/10.1016/j.rcrx.2020.100035>.
- Park, H., Sanguinetti, A. and Castillo-Cortes, G. (2017) EcoTrips: Leveraging Co-benefits and Metaphorical Metrics in a Mobile App to Promote Walking and Biking for Short Trips. In Marcus, A., Wang, W. (eds) *Proceedings of the International Conference of Design, User Experience, and Usability, Vancouver, BC, Canada*, pp. 60–76. Springer, Cham, Switzerland.
- Pawluk De-Toledo, K., O'Hern, S. and Koppel, S. (2022) Travel behaviour change research: a scientometric review and content analysis. *Travel Behav. Soc.*, **28**, 141–154. <https://doi.org/10.1016/j.tbs.2022.03.004>.
- Petri, M., Pratelli, A., Farina, A., Buffi, A., Franchina, V., Nepa, P., Giannecchini, S. and Iasio, C. (2018) The SaveMyBike Project: ITS Technologies and Rewarding Policies to Improve Sustainable Mobility in Cities. In *Proceedings of the Transportation Research Arena TRA, Vienna, Austria*, 16–19 April 2018, pp. 1–10.



- Petrunoff, N., Rissel, C. and Wen, L. M. (2016) The effect of active travel interventions conducted in work settings on driving to work: a systematic review. *J. Transp. Heal.*, **3**, 61–76.
- Piras, F., Sottile, E., Tuveri, G. and Meloni, I. (2022) Does the joint implementation of hard and soft transportation policies lead to travel behavior change? An experimental analysis. *Res. Transp. Econ.*, **95**, 101233–101233. <https://doi.org/10.1016/j.retrec.2022.101233>.
- Pourhashem, G., Malichová, E., Piscová, T. and Kováčiková, T. (2022) Gender difference in perception of value of travel time and travel mode choice behavior in eight European countries. *Sustain. For.*, **14**, 10426.
- Prochaska, J. O. and DiClemente, C. C. (1983) Stages and processes of self-change of smoking: toward an integrative model of change. *J. Consult. Clin. Psychol.*, **51**, 390–395. <https://doi.org/10.1037//0022-006x.51.3.390>.
- Reeves, B. and Nass, C. (1996) *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Cambridge University Press, Cambridge.
- Ruiz, T., Arroyo, R., Mars, L. and Casquero, D. (2018) Effects of a travel behaviour change program on sustainable travel. *Sustain. For.*, **10**, 4610. <https://doi.org/10.3390/su10124610>.
- Scheepers, C. E., Wendel-Vos, G. C. W., den Broeder, J. M., van Kempen, E. E. M. M., van Wesemael, P. J. V. and Schuit, A. J. (2014) Shifting from car to active transport: a systematic review of the effectiveness of interventions. *Transp. Res. A Policy Pract.*, **70**, 264–280. <https://doi.org/10.1016/j.tra.2014.10.015>.
- Schwartz, S. H. (1977) Normative influences on altruism. *Adv. Exp. Soc. Psychol.*, [online], **10**, 221–279. [https://doi.org/10.1016/s0065-2601\(08\)60358-5](https://doi.org/10.1016/s0065-2601(08)60358-5).
- Semenescu, A., Gavreliuc, A. and Sârbescu, P. (2020) 30 years of soft interventions to reduce car use—a systematic review and meta-analysis. *Transp. Res. Part D: Transp. Environ.*, **85**, 102397.
- Sherwin, K. (2018) *Card Sorting: Uncover Users' Mental Models for Better Information Architecture*. <https://www.nngroup.com/articles/card-sorting-definition>
- Skarin, F., Olsson, L. E., Roos, I. and Friman, M. (2017) The household as an instrumental and affective trigger in intervention programs for travel behavior change. *Travel Behav. Soc.*, **6**, 83–89. <https://doi.org/10.1016/j.tbs.2016.08.001>.
- Sottile, E., Giachetti, T., Tuveri, G., Piras, F., Calli, D., Concas, V., Zamberlan, L., Meloni, I. and Carrese, S. (2021) An innovative GPS smartphone based strategy for university mobility management: a case study at the University of RomaTre, Italy. *Res. Transp. Econ.*, **85**, 100926. <https://doi.org/10.1016/j.retrec.2020.100926>.
- Statista Research Department (2024) *Transportation Emissions Worldwide*. Available at: <https://www.statista.com/topics/7476/transportation-emissions-worldwide/#topicOverview>.
- Tang, T. and Bhamra, T. (2008) Changing Energy Consumption Behaviour through Sustainable Product Design. In *DS 48: Proceedings DESIGN 2008, International Design Conference 2008*, Dubrovnik, Croatia.
- Tilley, S. and Houston, D. (2016) The gender turnaround: young women now travelling more than young men. *J. Transp. Geogr.*, **54**, 349–358.
- Tsirimpa, A., Polydoropoulou, A., Pagoni, I. and Tsouros, I. (2019) A reward-based instrument for promoting multimodality. *Transport. Res. F: Traffic Psychol. Behav.*, **65**, 121–140. <https://doi.org/10.1016/j.trf.2019.07.002>.
- Walsh, P. R. and Dodds, R. (2022) The impact of intermediaries and social marketing on promoting sustainable behaviour in leisure travellers. *J. Clean. Prod.*, **338**, 130537. <https://doi.org/10.1016/j.jclepro.2022.130537>.
- Wang, R., Bush-Evans, R., Arden-Close, E., Bolat, E., McAlaney, J., Hodge, S., Thomas, S. and Phalp, K. (2023) Transparency in persuasive technology, immersive technology, and online marketing: facilitating users' informed decision making and practical implications. *Comput. Hum. Behav.*, **139**, 107545. <https://doi.org/10.1016/j.chb.2022.107545>.
- Wu, S., Bai, Q. and Sengvong, S. (2018) GreenCommute: an influence-aware persuasive recommendation approach for public-friendly commute options. *J. Syst. Sci. Syst. Eng.*, **27**, 250–264. <https://doi.org/10.1007/s11518-018-5368-6>.
- Zachrisson, J. and Boks, C. (2012) Exploring behavioural psychology to support design for sustainable behaviour research. *J. Des. Res.*, **10**, 50–66.