Overcoming psychological barriers to pro-environmental behaviour change: the use of virtual reality

By

Catherine Alexandra Graves

Submitted in accordance with the requirements for the degree of Doctor of Philosophy.

The University of Leeds

Sustainability Research Institute

School of Earth and Environment

December 2023

Declaration of Authorship

I confirm that the work submitted is my own, except where work which has formed part of jointly authored publications has been included. My contribution and the other authors to this work has been explicitly indicated below. I confirm that appropriate credit has been given within the thesis where reference has been made to the work of others.

The publication 'Graves, C. and Roelich, K. 2021. Psychological Barriers to Pro-Environmental Behaviour Change: A Review of Meat Consumption Behaviours. Sustainability. 13(21), p.11582.' is included as Chapter 5 in this thesis.

The conceptual underpinnings, research design, data collection and analysis, and original draft was performed by the candidate. K Roelich provided supervision and edits on original drafts and revisions.

Acknowledgements

This PhD has been funded through the University of Leeds Global Challenge Scholarship Fund. Many thanks to the University of Leeds 'Pandemic Support Scheme' and the School of Earth and Environment 'Pandemic Support Scheme'. Thanks to the Rapid Evidence Synthesis Training (REST) programme; a collaboration between the University of Leeds, The University of Newcastle and the N8 AgriFood Programme and supported by Research England QR-SPF funds from The University of Leeds and University of York. Also, a big thanks to all the participants who contributed to this work.

Thank you to my supervisors Dr. Katy Roelich and Prof. Milena Büchs for their endless support and advice. Katy – thank you for believing in this research project when it was a just vague note at the bottom of my 'PhD ideas' google doc. I am so grateful for all your mentorship and care. Milena – thank you for your unwavering calmness and guidance. I'm very lucky to have such inspirational women supporting me.

During this time, I have worked on various projects alongside the PhD. Thanks to the team at Defra, and Dr. Jon Swords and the BAFTA-albert team for their flexibility and understanding while I finished off my PhD alongside full-time work. Thanks to Dr. Harriet Thew for her email "do you want a job?" which led to a great year working on climate change education research. Thanks to Margo, Kate and Robin for all the odd jobs and who always have the crown for being the most fun team.

This PhD has been a marathon, and would have been impossible without Kate, Ruth, and Kat; you have got (/dragged) me through this, and I'll never be able to thank you enough. Alice, thank you for all the laughs during our writing/coffee catch ups where, despite them being 90% chat, literally most of this thesis was written. Ellie, thank you for the pep talk every morning. Demaude, thank you for your endless cheer-leading and 9-minute voice notes. Thanks to Julia and Bob for the getaways! Thanks to my mum and dad for their support, I'm glad I have finally answered the question of 'when will you finish?'. Finally, thanks to my partner Tom for the infinite cups of tea, boundless enthusiasm, and unwavering, joyful silliness.

Abstract

Motivation

This research originated from discussions with practitioners who used virtual reality (VR) as a communication tool to share climate stories. They identified a dearth of impact evaluations and evidence to support the growing use of VR for social and environmental good. Virtual reality was considered to overcome the psychological distance of climate change, which then was assumed to lead to pro-environmental behaviour change.

Purpose

This work explores these key assumptions and brings together this phenomenological approach with broader questions around the consideration of psychological barriers including psychological distance in climate communications and discourse.

Approach and methods

This research is grounded in a critique of the discourse around pro-environmental behaviour change. This utilises the Kollmuss and Agyeman (2002) model of pro-environmental behaviour change in order to consider behaviour holistically and non-linearly, and integrates psychological barriers in order to test the assumptions around the use of VR as a communication tool for climate.

This research utilises and critiques a systematic review, a rapid evidence review and an experimental design to explore these questions.

Findings

Phase 1 synthesised existing research around VR and pro-environmental behaviour and identified key research gaps; primarily around the focus on low-

impact behaviours, over short time periods, with a lack of focus on psychological barriers.

Phase 2 focused on a high impact behaviour (meat consumption) and identified a new conceptualisation of the psychological barriers to pro-environmental behaviour change; with barriers manifesting as blocks or as gaps.

Phase 3 provided empirical evidence to show that psychological distance was reduced after viewing a virtual reality experience.

Contribution

This research provides a novel theoretical integration of psychological distance and the Kollmuss and Agyeman (2002) model of pro-environmental behaviour and evaluates its usefulness.

Methodologically, a new systematic review framework is developed for environmental social science. Insights are also produced in relation to using virtual reality in experimental designs, with recommendations for researchers and practitioners for its use.

Empirically, new assessments of the existing literature around virtual reality and pro-environmental behaviour change, and psychological barriers around meat consumption are conducted. Additionally, an experiment identifies new empirical contributions around psychological determinants, outcomes and barriers to pro-environmental behaviour change.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

COP – Conference of the Parties

CNS – Connection to nature scale

GHG – Greenhouse gas emissions

INS – Inclusion of nature in self

IVET – Immersive virtual environment technology

K&A – Kollmuss and Agyeman (2002) model

PBs – Psychological barriers

PEB – Pro-environmental behaviour

PEBC – Pro-environmental behaviour change

REBS – Recurring Pro-environmental Behavior Scale

RER – Rapid evidence review

SR – Systematic review

TPB – Theory of planned behaviour

VBN – Value-belief-norm theory

VR – Virtual reality

XR – Extended reality

Chapter 1 Introduction

1.1 Scale and pace of change required.

The climate and ecological crises require changes to society at macro and micro scales, from international and multi-national policy-settings, to the household and individual level changes which this research focuses on. The human impact on the environment is multi-faceted and inter-related, much as our response to the issues must be, therefore the joint crises of climate and biodiversity must be dealt with in concert.

There have been several key steps forward at an international level in recent years, with COP21 in Paris (in 2015) marking a collective agreement to keep the global mean temperature rise 'well below' 2°C on baseline levels, and more recently, the Montreal Agreement (COP15 in 2022) where a global biodiversity framework was adopted. International direction and frameworks are invaluable in providing the structure in which national governments work within. However, despite some positive advancements, the pace of change is widely accepted to be insufficient to address the joint crises (Bryndum-Buchholz, 2022). In the years since COP21 in Paris, efforts to agree to an implementation plan have faltered, all while climate impacts are already felt. If current policies are not improved upon, warming of between 2-5°C could occur by 2100, causing increasingly extreme weather patterns, accelerating sea level rise and instability of degraded ecosystems (Betts and Brown, 2021). If all current policies are achieved, at international and national level, 2.7°C warming is still predicted to occur (from pre-industrial levels) by 2100 (Climate Action Tracker, 2022), which highlights the scale and urgency of action required to mitigate this.

The long timescales often discussed in relation to climate change are assumed to be a barrier to engagement and action (Maiella et al., 2020), at all scales including individual responses. Therefore, it can be useful to utilise communication technology to highlight the more immediate threats posed to overcome this barrier to behaviour change in order to enable individual action. For example, by 2040, if the projected 0.5°C temperature rise occurs, this will likely result in increased wildfires, food supply disruption and a mass die-off of coral reefs (IPCC, 2022). Here, in 2023, the impacts of climate change and ecological destruction have been shown to include changes to the structure, species range and phenology of every ecosystem (see **Figure 1**). However, caution should be applied due to the imbalance in measurement and reporting across harder to reach and under-examined areas. The impacts of climate

change are already felt in relation to extreme weather, with heatwaves increasing and accelerating due to climate change (Perkins-Kirkpatrick and Lewis, 2020). In 2019, 396 natural disasters occurred (including cyclones, wildfires, flooding), many of which were linked to climate change and have implications for human well-being (Ebi et al., 2021). Recently, extreme temperatures experienced in 2022 across Europe, lead to 61,672 estimated heat-related deaths between May and September (Ballester et al., 2023).

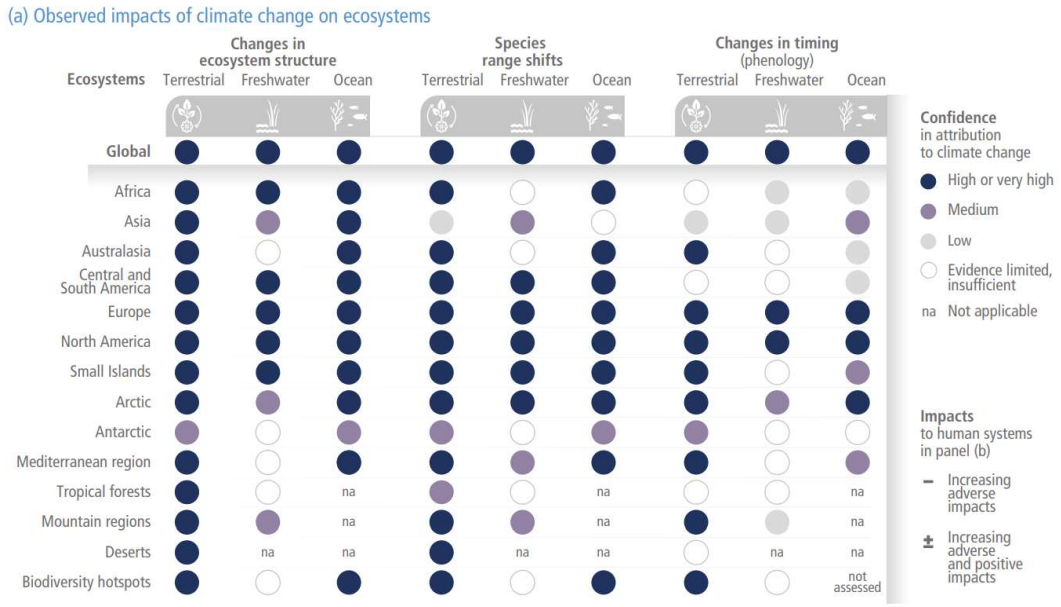


Figure 1 "Observed impacts of climate change on ecosystems" (IPCC, 2022, p.10)

1.2 Policy context

There is an ‘emissions gap’ between the required path the UK needs to be on to meet agreements set out in the Paris Accords and the Nationally Defined Contributions (NDCs), and the current policies aimed to reduce emissions (van Soest et al., 2021). Individual behaviour change can contribute to closing this gap and making demand-side reductions in emissions (and other environmental costs) (Wynes and Nicholas, 2017). The ‘avoid-shift-improve’ demand side mitigation framework (Creutzig et al., 2022) outlines demand-side reductions as mitigation strategies which reduce primary energy demand by considering end-use. This framework also centres the role of individual decision-making and behaviour within an infrastructural system.

UK policy options tend to err away from behavioural facilitation or encouragement, despite work in the 2000s from the Department for Environment, Food and Rural Affairs (DEFRA), with reports such as 'Changing Behaviour Through Policy Making' (DEFRA, 2005) and the Framework for Pro-environmental Behaviours (DEFRA, 2008). Climate and energy policy in the UK focussing on encouraging individual behaviour change is generally considered to be lacking (Lorenzoni et al., 2007). Despite the DEFRA Framework for Pro-environmental Behaviours report in 2008, UK policy still is primarily focused on reducing emissions intensity of energy and other technological mitigation strategies (Nelson and Allwood, 2021). Despite widespread political and public understanding of the need to alter individual and household behaviours, policy is muted and unambitious due to the focus on long-term technocratic policy options (Dietz et al., 2009).

The information deficit model is a widely critiqued model of predicting pro-environmental behaviour, yet is still the model that communications and policy commonly apply, by assuming that increasing awareness or knowledge about environmental issues will translate into increased pro-environmental behaviour (Brick and Lai, 2018; Clayton et al., 2015; Kollmuss and Agyeman, 2002). The process from understanding to action has rarely been empirically proven to be linear, and it is widely understood that information is mediated through wider contextual factors such as social norms, values and personal experience (Lorenzoni et al., 2007). Therefore, integrating the complexity of behavioural responses into policy can be difficult. Policy strategies have centred around nudges or choice architecture, in response to research evidencing the low effectiveness of policy which assumes a rational mental model within the individual (Creutzig et al., 2016).

The link between policy and individual behaviour is not one directional. Acceptance of environmental policy has been found to be a strong indicator of other pro-environmental behaviours, and has even been argued to be a catalyst for individual behaviour change (Stern, 2020).

1.3 Role of individual behaviour

Due to the gap between the mitigation projections associated with national level technological policies and keeping warming below 1.5°C, other actions are required to bridge the policy gap (Schleussner et al., 2016). Individual behaviour is crucial to this, in addition to collective and system level action. This is a global

issue, but individuals have agency and responsibility to reduce their climate 'footprint'. This research operates on the principle that individual decision-making underpins decision-making at community, national and international levels. However, it is important to acknowledge the wide global variance in historic responsibility for climate change and competing considerations such as opportunities for human development. Direct impacts of household behaviours account for approximately 72% of global GHG emissions (Dubois et al., 2019), with the UK's figure equating to 82% of national emissions (Hertwich and Peters, 2009). This figure highlights the emissions reduction potential of behaviour changes at an individual, household, community and national level. Currently however, behavioural interventions are under-utilised through policy (Stern, 2020), therefore other intervention mechanisms such as communications and public engagement are necessary to facilitate the required societal shift in norms and pro-environmental behaviour change.

How to design effective behavioural interventions which encourage pro-environmental behaviour change has been a growing area of research and policy in the last few years (Benz et al., 2022). Pro-environmental behaviour change can include conscious and unconscious behavioural shifts which reduce one's negative impact on the environment (Steg and Vlek, 2009).

Within research and practice, there is an unequal focus on certain components or drivers of behaviour, with environmental concern and attitudes dominating the research discourse, with a dearth of work focusing on barriers to behaviour change, and importantly, the psychological components of these barriers. There is a challenge here to understand behavioural change mechanisms, assess the effectiveness of behavioural interventions, and to explore this in the context of rapidly changing communication technology.

1.4 Conveying the message

The communication of the causes, impacts and solutions to climate change are critical for science, policy and other interventions to be effective (Pearce et al., 2015; Moser, 2016). The roles communication technology, specifically virtual reality (VR), can play in this are introduced here.

Climate change communication has been an area of research for decades, with huge bodies of work examining the use of print and news media, broadcast media, advertising, campaigns and policy communications on a range of outcomes including household behaviours, societal norms, consumer spending

and policy effectiveness (Schäfer and Schlichting, 2014; Pearce et al., 2015). Communication of climate change and the complexities (and uncertainties) around impact, policy implications, differentiated responsibilities, and the day-to-day effects on the individual can be approached in a multitude of ways across a multitude of media. Effective communication is essential for encouraging new behaviours, changing existing behaviours and establishing habits (Maibach et al., 2008). Media has a huge role in shaping public perceptions of climate change, especially around risk perception (Happer and Philo, 2016). Large scale attitudinal change and increases in public concern have been found to have been catalysed through various media (Carmichael and Brulle, 2017).

The ‘Blue Planet effect’ has been identified, with the release of ‘Blue Planet II’ (from the BBC’s Natural History Unit (2017)) resulting in an increase in online searches for ‘microplastics’ related terms, and a long-lasting increase in media coverage of the issue of marine plastic pollution (Jones et al., 2019; Males and Van Aelst, 2021). Behaviourally however, no effect on directly measured behaviour was found despite an increase in knowledge and attitudes (Dunn et al., 2020). ‘The Day After Tomorrow’ (2004) has been widely studied as a behavioural intervention or turning point in the climate change communications discourse. Short term increases in pro-environmental attitudes were associated with seeing the film, along with higher concern and risk perception (Lowe et al., 2006), and pro-environmental behavioural intention (Leiserowitz, 2004). However, the longevity of these effects have been questioned (Sakellari, 2015).

Communication through media such as this often taps into emotional response, with a view to change ‘hearts and minds’, especially within media such as disaster movies, scripted drama, or campaigning content. However, the assumption that changing ‘hearts and minds’ results in a subsequent behavioural change requires more examination.

Virtual Reality (VR) is expanding in its use as a communication tool for climate and sustainability, in line with its accessibility and content being available more broadly. Research on the use of VR for behaviour change has increased rapidly over the last 10 years, and the implications this may present for pro-environmental interventions. Due to the increased immersivity and perceived realism VR provides, it has been widely assumed to bridge the psychological gap between individuals and the impacts of climate change (Buljat, 2022), in order to effect behaviour change. However, these assumptions need to be more thoroughly tested.

1.5 Rationale behind the research and research questions

The origin of this project is rooted in observations and conversations with practitioners and experts in the fields of using Immersive Technology/Virtual Reality (VR) for campaigning and 'social good'. Through discussions with environmental communicators using VR at COP23 (November 2017) and at the Global Festival of Action on the Sustainable Development Goals (March 2018), a research need was identified due to the rapid expansion of virtual reality and other immersive technologies being used as a communication tool by NGOs and campaigning organisations such as the UN and World Bank. Immersive technologies were being used for a variety of purposes including raising awareness of environmental/social issues amongst the general public, or targeting political figures or organisations, raising funds, telling previously untold stories or generating empathy. The use of stories and documentaries told through VR by these organisations for sustainability purposes lacked an evidence base to justify their use or expansion by funders.

Therefore, this research aims to contribute to this practice and research gap, by addressing questions of additionality and effectiveness of VR within the context of environmental campaigns and individual behaviour. This research aims to test the assumptions associated with the use of VR to reduce psychological distance of climate change. Psychological distance (the distance between an individual and their perception of an issue/person/group) is assumed to be reduced using VR due to the immersiveness of the technology. This research also aims to develop understanding of the impact of psychological barriers on pro-environmental behaviour more broadly, in order to provide insights for future interventions (further detail on research questions in Chapter 2.3).

1.6 Structure of the thesis

The structure of this thesis has been significantly impacted by the Covid-19 pandemic, the uncertainty that brought, and the ramifications of that on my PhD journey. Initially, I had intended on submitting through the alternative format (i.e. by publication), hence the Chapters 4-6 are structured as papers. I switched to the traditional format thesis late in my PhD due to delays and uncertainty during the review process for Chapter 4 (systematic review). The decision was made to switch to traditional thesis in order to have the timeline under my own control, and not be dependent on a generally lengthy and uncertain peer-review process. Despite this disappointment, the process of developing the papers for

publication was a useful one and has resulted in gaining useful feedback from peer-reviewers for Chapters 4 and 5. Therefore, the structure of Chapters 4-6 includes additional introduction and methods detail where it is relevant. I decided to keep the thesis structured by paper as Chapter 4 and 5 address the two different components of the overarching research topic (virtual reality, and psychological barriers respectively), and Chapter 6 brings those two areas together.

This thesis begins with a review of the literature, divided into the two key concepts this research brings together; pro-environmental behaviour change and climate change communication, in order to situate and contextualise the subsequent work. Chapter 3 then outlines the methods for the project, explaining the approaches used to answer the research questions. Chapter 4 follows with a systematic literature review exploring the current research body around virtual reality and pro-environmental behaviour. Chapter 5 explores the psychological barriers associated with reducing meat consumption through a rapid evidence review. Chapter 6 presents findings from an experimental study which brings the previous two sets of findings together and explores the impact of a VR intervention on a range of pro-environmental determinants, psychological barriers and behavioural outcomes, with a specific focus on meat consumption. Chapter 7 brings these three pieces of research together in a discussion around the implications for environmental communications and the use of VR in research. Chapter 8 follows with a reflective piece drawn from a five-year research diary recorded throughout the research process, which addresses the contributions this thesis makes. Chapter 9 concludes the research, with a summary of findings and contributions.

1.7 References

Ballester, J., Quijal-Zamorano, M., Méndez Turrubiates, R.F., Pegenaute, F., Herrmann, F.R., Robine, J.M., Basagaña, X., Tonne, C., Antó, J.M. and Achebak, H. 2023. Heat-related mortality in Europe during the summer of 2022. *Nature Medicine*. **29**(7), pp.1857–1866.

Benz, A., Formuli, A., Jeong, G., Mu, N. and Rizvanovic, N. 2022. Environmental psychology: Challenges and opportunities for a sustainable future. *PsyCh Journal*. **11**(5), pp.767–773.

Betts, R.A. and Brown, K. 2021. *Introduction* [Online]. London: Prepared for the Climate Change Committee. [Accessed 13 January 2023]. Available from: https://www.ukclimaterisk.org/wp-content/uploads/2021/06/Technical-Report-The-Third-Climate-Change-Risk-Assessment.pdf.

Brick, C. and Lai, C.K. 2018. Explicit (but not implicit) environmentalist identity predicts pro-environmental behavior and policy preferences. *Journal of Environmental Psychology*. **58**, pp.8–17.

Bryndum-Buchholz, A. 2022. Keeping up hope as an early career climate-impact scientist. *ICES Journal of Marine Science*. **79**(9), pp.2345–2350.

Buljat, B. 2022. Environmental policy and immersive technologies. *Journal of Behavioral Economics for Policy*. **6**(Special Issue 1), pp.41–47.

Carmichael, J.T. and Brulle, R.J. 2017. Elite cues, media coverage, and public concern: an integrated path analysis of public opinion on climate change, 2001–2013. *Environmental Politics*. **26**(2), pp.232–252.

Clayton, S., Devine-Wright, P., Stern, P.C., Whitmarsh, L., Carrico, A., Steg, L., Swim, J. and Bonnes, M. 2015. Psychological research and global climate change. *Nature Climate Change*. **5**(7), pp.640–646.

Climate Action Tracker 2022. 2100 Warming Projections: Emissions and expected warming based on pledges and current policies. *2100 Warming Projections: Emissions and expected warming based on pledges and current policies*. [Online]. [Accessed 13 January 2023]. Available from: https://climateactiontracker.org/global/temperatures/.

Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y. and Seto, K.C. 2016. Beyond Technology: Demand-Side Solutions for Climate Change Mitigation. *Annual Review of Environment and Resources*. **41**(1), pp.173–198.

Creutzig, F., Roy, J., Devine-Wright, P., Díaz-José, J., Geels, F., Grubler, A., Maïzi, N., Masanet, E., Mulugetta, Y. and Onyige-Ebeniro, C.D. 2022. *Demand, services and social aspects of mitigation*. Cambridge University Press.

DEFRA 2008. *A Framework for Pro-environmental Behaviours*. The Stationery Office, London: Department for Environment, Food and Rural Affairs.

DEFRA 2005. *Changing Behaviour Through Policy Making*. The Stationery Office, London: Department for Environment, Food and Rural Affairs.

Dietz, T., Gardner, G.T., Gilligan, J., Stern, P.C. and Vandenbergh, M.P. 2009. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the National Academy of Sciences*. **106**(44), pp.18452–18456.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K.R., Ceron, J.P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V.R. and Sauerborn, R. 2019. It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. *Energy Research & Social Science*. **52**, pp.144–158.

Dunn, M., Mills, M. and Verissimo, D. 2020. Evaluating the impact of the documentary series Blue Planet II on viewers' plastic consumption behaviors. *CONSERVATION SCIENCE AND PRACTICE*. **2**(10).

Ebi, K.L., Vanos, J., Baldwin, J.W., Bell, J.E., Hondula, D.M., Errett, N.A., Hayes, K., Reid, C.E., Saha, S., Spector, J. and Berry, P. 2021. Extreme Weather and Climate Change: Population Health and Health System Implications. *Annual Review of Public Health*. **42**(1), pp.293–315.

Happer, C. and Philo, G. 2016. New approaches to understanding the role of the news media in the formation of public attitudes and behaviours on climate change. *European Journal of Communication*. **31**(2), pp.136–151.

Hertwich, E.G. and Peters, G.P. 2009. Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology*. **43**(16), pp.6414–6420.

IPCC 2022. Summary for Policymakers *In*: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Online]. Cambridge, UK:

Cambridge University Press. [Accessed 13 January 2023]. Available from: https://www.cambridge.org/core/product/identifier/9781009157940/type/book.

Jones, J.P.G., Thomas-Walters, L., Rust, N.A. and Veríssimo, D. 2019. Nature documentaries and saving nature: Reflections on the new Netflix series Our Planet. *People and Nature*. **1**(4), pp.420–425.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? *Environmental Education Research*. **8**(3), pp.239–260.

Leiserowitz, A.A. 2004. Day After Tomorrow: Study of Climate Change Risk Perception. *Environment: Science and Policy for Sustainable Development*. **46**(9), pp.22–39.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change*. **17**(3–4), pp.445–459.

Lowe, T., Brown, K., Dessai, S., Doria, M., Haynes, K. and Vincent, K. 2006. Does tomorrow ever come? Disaster narrative and public perceptions of climate change. *Public Understanding of Science*. **15**(4), pp.435–457.

Maibach, E.W., Roser-Renouf, C. and Leiserowitz, A. 2008. Communication and Marketing As Climate Change–Intervention Assets: A Public Health Perspective. *American Journal of Preventive Medicine*. **35**(5), pp.488–500.

Maiella, R., La Malva, P., Marchetti, D., Pomarico, E., Di Crosta, A., Palumbo, R., Cetara, L., Di Domenico, A. and Verrocchio, M.C. 2020. The Psychological Distance and Climate Change: A Systematic Review on the Mitigation and Adaptation Behaviors. *Frontiers in Psychology*. **11**.

Males, J. and Van Aelst, P. 2021. Did the Blue Planet set the Agenda for Plastic Pollution? An Explorative Study on the Influence of a Documentary on the Public, Media and Political Agendas. *Environmental Communication*. **15**(1), pp.40–54.

Moser, S.C. 2016. Reflections on climate change communication research and practice in the second decade of the 21st century: what more is there to say? *WIREs Climate Change*. **7**(3), pp.345–369.

Nelson, S. and Allwood, J.M. 2021. Technology or behaviour? Balanced disruption in the race to net zero emissions. *Energy Research & Social Science*. **78**, p.102124.

Pearce, W., Brown, B., Nerlich, B. and Koteyko, N. 2015. Communicating climate change: conduits, content, and consensus. *WIREs Climate Change*. **6**(6), pp.613–626.

Perkins-Kirkpatrick, S.E. and Lewis, S.C. 2020. Increasing trends in regional heatwaves. *Nature Communications*. **11**(1), p.3357.

Sakellari, M. 2015. Cinematic climate change, a promising perspective on climate change communication. *Public Understanding of Science*. **24**(7), pp.827–841.

Schäfer, M.S. and Schlichting, I. 2014. Media Representations of Climate Change: A Meta-Analysis of the Research Field. *Environmental Communication*. **8**(2), pp.142–160.

Schleussner, C.-F., Rogelj, J., Schaeffer, M., Lissner, T., Licker, R., Fischer, E.M., Knutti, R., Levermann, A., Frieler, K. and Hare, W. 2016. Science and policy characteristics of the Paris Agreement temperature goal. *Nature Climate Change*. **6**(9), pp.827–835.

van Soest, H.L., Aleluia Reis, L., Baptista, L.B., Bertram, C., Després, J., Drouet, L., den Elzen, M., Fragkos, P., Fricko, O., Fujimori, S., Grant, N., Harmsen, M., Iyer, G., Keramidas, K., Köberle, A.C., Kriegler, E., Malik, A., Mittal, S., Oshiro, K., Riahi, K., Roelfsema, M., van Ruijven, B., Schaeffer, R., Silva Herran, D., Tavoni, M., Unlu, G., Vandyck, T. and van Vuuren, D.P. 2021. Global roll-out of comprehensive policy measures may aid in bridging emissions gap. *Nature Communications*. **12**(1), p.6419.

Steg, L. and Vlek, C. 2009. Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology. 29(3), pp.309–317.

Stern, P.C. 2020. A reexamination on how behavioral interventions can promote household action to limit climate change. *Nature Communications*. **11**(1), p.918.

Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*. **12**(7), p.074024.

Chapter 2 Literature review

2.1 Pro-environmental behaviour change

Human behaviour is involved in every process associated with greenhouse gas emissions and environmental consumption. This thesis considers pro-environmental behaviour to include every action (intentional or unintentional) as having an environmental and climate impact associated with it. Behaviours which result in a direct positive environmental or climate outcome, such as donating to environmental causes, planting trees, or engaging in civic activism, tend to be intentional 'pro-nature', 'pro-climate' or 'pro-environmental' value-based behaviours. However pro-environmental behaviour can extend far beyond this, into every component of work, home and leisure time. This research applies the normative assumption that individual behaviour change is required in order to mitigate climate change in the required timeframes. I acknowledge that widespread change needs to occur in a fair and just way, to live within ecological limits and planetary boundaries (O'Neill et al., 2018).

2.1.1 What are pro-environmental behaviours?

According to Kollmuss and Agyeman (2002), pro-environmental behaviour is defined as "behaviour that consciously seeks to minimise the negative impact of one's actions on the natural and built world (e.g. minimize resource and energy consumption, use of non-toxic substances, reduce waste production)" (p.240). . Jensen (2002) critiques the scope of Kollmuss and Agyeman's (2002) definition and advocate for an 'action-oriented' knowledge. This builds on Stern's (2000) distinction between 'impact-oriented' and 'intent-oriented' approaches to research on pro-environmental behaviour. This thesis takes a view that positive impact is of primary importance, while intention also holds a key place in the behavioural mechanism. Over the last 20 years since Kollmuss and Agyeman's definition, the conceptualisation of pro-environmental behaviour has evolved and been debated extensively. Siegel et al. (2018) argue that the binary categorisation of intentional and unintentional action is too simplistic and potentially unhelpful, as it does not reflect the complexity of factors (internal and

external) which determine a behaviour. Considering impact as the overarching goal of pro-environmental behaviour, this thesis supports Lange and Dewitte's (2019) definition which includes positive acts which help the environment and the avoidance of acts which harm it. Gatersleben (2023) argues that the way pro-environmental behaviour is defined impacts how it is researched, what is measured and how the conclusions are drawn. Therefore, this work combines these definitions and parameters of pro-environmental behaviour to create the following broad definition:

> Pro-environmental behaviours are the conscious or unconscious actions of an individual which either have a directly positive impact on the environment, or act as an environmental 'saving' against an alternative or baseline behaviour.

Pro-environmental behaviour can be categorised in a variety of ways, such as 'one-off' (e.g. purchasing an energy efficient appliance) or habitual behaviours (walking to work). Alternatively, pro-environmental behaviours and actions can be divided into groups, sometimes referred to as 'domains' (Gifford et al., 2011), for example energy, consumption or travel behaviours. The notion of behavioural clustering (Whitmarsh and O'Neill, 2010) refers to domains of behaviours, which can be categorised by purchasing decisions, habits, and recycling (in relation to energy-related behaviours, (Barr et al., 2005)), but also by geographical area (Verplanken and Roy, 2016); motivational causes (Thøgersen and Ölander, 2006), or curtailment/efficiency behaviours (Gifford et al., 2011). Considering behaviours as groups of actions can help understand them as interrelated factors and enables interventions to be created which avoid potential negative spillover or rebound effects.

Research in this sphere has been dominated by studies focused on low-impact and small-scale behaviours (e.g. recycling and small-scale energy reductions such as changing to LED light bulbs (Rosa and Collado, 2020)). This is especially prominent within experimental research, possibly due to the ease of measurement (Thøgersen and Noblet, 2012), therefore there is need for more research on high-impact behaviours (Gifford et al., 2011). High impact behaviour changes can be defined as actions which reduce the carbon footprint of the individual by 0.8tCO2e/year (Wynes and Nicholas, 2017), which can

include living car free, having one fewer child, eating a vegan diet, and avoiding air travel (Wynes and Nicholas, 2017; Ivanova et al., 2020). This research will not quantify a boundary for the classification of ‘high impact’ behaviours as it will cover high impact behaviours across different behavioural domains (which may not be comparable in terms of environmental gain or cost avoided), and it focusses on repeatable actions (i.e. eating a plant-based diet) as opposed to one-off acts (i.e. purchasing an energy efficient fridge).

2.1.2 Behavioural theory

The theories in the field of pro-environmental behaviour change which are explored in this thesis relate to behaviour change, interventions, and barriers to behaviour change. These are three interrelated components which are necessary to outline and explore to understand the effectiveness of an intervention which aims to change behaviour. In order to analyse behaviour change holistically, all three components should be considered.

Behavioural theory can enable us to organise behavioural determinants and factors, design interventions to manipulate them, and evaluate the effectiveness of those interventions. Several theoretical frameworks and models have historically dominated the social-psychological discourses of pro-environmental behavioural research and policy, primarily the Theory of Planned Behaviour (Ajzen, 1991), and its predecessor the Theory of Reasoned Action, as well as the value-belief-norm theory (Stern et al., 1999). The enduring use of these structures can be found in research, if not through explicit reference, but through the selection and use of certain behavioural determinants and metrics. For instance, the psychological components of pro-environmental behavioural research is dominated by work on attitudes, values and behavioural intention. These dominant paradigms often conceptualise behaviour as a linear process. A balance needs to be sought between comprehensiveness and usability within theoretical frameworks, and a narrow group of behavioural determinants is often considered (and therefore measured) when using these models. A critique of these dominant theoretical approaches is explored by Gifford (2006) in their outlining of the ‘general model of social dilemmas’ and through their work on

psychological barriers to pro-environmental behaviour change (Gifford, 2011; Gifford et al., 2011; Gifford and Chen, 2017). The primary critique which Gifford et al. (2011) centres on is the absence of psychological barriers which are framed as of equal importance to behavioural determinants within dominant theoretical paradigms. This thesis conceptualises behaviour and behaviour change as a non-linear, multifaceted, complex system (Larson et al., 2015), drawing from the Kollmuss and Agyeman (2002) model of pro-environmental behaviour.

2.1.2.1 Behavioural interventions

In pro-environmental behaviour change literature, there is extensive research on how intervention and evaluation strategies change behaviour most effectively. There are several different disciplines and schools of thought around this. Behavioural economics approaches (including 'nudges' defined by Thaler and Sunstein (2008)) involve interventions such as choice architecture and other indirect interventions (e.g. default options). Social marketing approaches include interventions which are easy and attractive (Involve, 2010), which can include nudge interventions but also is heavily dependent on communications. Social practice theory is a lens which views behaviour as the outcomes and 'practices' of individual and group behaviours (as opposed to the determinants of behaviour) (Welch, 2017) and consider interventions which challenge the existing structures and systems from which practices emerge (Hampton and Adams, 2018). Within this thesis, behavioural interventions are defined as strategies aimed to improve pro-environmental outcomes (Steg and Vlek, 2009).

Influenced primarily by environmental psychology within this thesis, behavioural interventions can be categorised as "information provision, feedback, goal setting, commitment, incentives and choice architecture" (Van Valkengoed et al., 2022, p1484). Grilli and Curtis (2021, p1) categorise interventions (or treatments) as "education and awareness, outreach and relationship building, social influence, nudges and behavioural insights, and incentives". Despite this slight variation in classification, both agree that targeted approaches which

consider the internal and external system in which the desired behaviour operates within is required for effective intervention. Understanding both the behavioural determinants and barriers is crucial in order to utilise them to construct behavioural interventions. The effectiveness of behavioural interventions increases when behavioural theory is integrated into the design of the intervention, by identifying the key behavioural determinants for the desired outcome, and targeting interventions accordingly (Klöckner, 2013).

Interventions can occur at all scales from influencing individual decisions to national policy. Large-scale interventions can include command-and-control/regulations, market-based instruments, or behaviour change interventions (Stern, 2020). For instance, the 5p plastic bag charge provides a successful case study for regulations catalysing behaviour change, as it resulted in a 95% reduction in plastic bag sales from major supermarkets (DEFRA and Pow, 2021). Behaviour change interventions can include instruments such as “information provision, appeals to values and norms, engagement, and restructuring choice options (so-called nudges)” (Stern, 2020, p1). Environmental structuring can come in the form of placement of items on a supermarket shelf, where product placement influences purchase likelihood (Glanz et al., 2012). ‘Nudge’ interventions generally have a higher public acceptance compared to other policy approaches (Gómez-Donoso et al., 2021).

Interventions which address the psychological distance of climate change are largely focused on communication, of the perceived risk or threat. Emotive communications strategies have been shown to bridge psychological distance (Van Boven et al., 2010) as well as engaging communications such as gaming (Fox et al., 2020). Opportunities to catalyse new positive behaviours have been found to occur at key life events or life changes, for instance when moving house or changing jobs (Kemper, 2020).

Local and community interventions can include social marketing approaches (Haq et al., 2013), educational initiatives (Wi and Chang, 2019), and local government schemes, such as those which encourage active travel or engagement with nature (Rosa and Collado, 2020). There is an opportunity to align environmental and climate policy interventions with other social issues such as health, which could enable co-benefits and potential positive spillovers.

Designing behavioural interventions through co-benefits of pro-environmental behaviours could enable a greater uptake of behaviour change, by targeting different individuals or groups through different values (e.g. by targeting pro-self values rather than pro-social/pro-environmental (Tyers, 2018)). Different motivations for behaviour and behaviour change can be used to overcome barriers to change through co-benefits or positive spillovers of interventions.

2.1.2.2 Spillover effects

Spillover is the concept that one behaviour will lead to other (positive) behavioural changes within and across behavioural domains. For instance, an individual engaging in energy saving behaviours resulting in an increased engagement with other cost-saving behaviours such as reducing food waste. However, negative spillover (also called the 'rebound effect' in some contexts (Herring and Sorrell, 2009)) conceptualises the process where, taking the same example, the individual has saved money in the first instance, which they then use to spend on high-carbon purchases, negating the initial pro-environmental outcome. Spillover can be categorised further, into 'promoting', 'permitting', and 'purging' spillover, where 'promoting' refers to positive behaviour 1 resulting in positive behaviour 2, 'permitting' refers to positive behaviour 1 results in negative behaviour 2, and 'purging' refers to negative behaviour 1 resulting in positive behaviour 2, out of a desire to mitigate the first behaviour (Dolan and Galizzi, 2015).

Evidence exploring the effect of positive and negative spillover have found mixed results, with research finding positive, negative or no effect between and across behaviours (Nash et al., 2017; Maki et al., 2019), however is crucial to consider when designing and evaluating interventions. The reasons underlying this process are often assumed to be conscious to some degree, with mental or emotional accounting processes determining a positive, negative or no spillover effect (Capstick et al., 2019). This can include moral licensing, where an individual may feel they are 'in credit' with a pro-environmental behaviour, and therefore allowed to conduct a negative behaviour as compensation (Capstick et al., 2019, Clot et al., 2022). The role of morals and value-based judgements

have been explored within other pro-social behaviours and across issues such as health (Chiou et al., 2011), and were also found to impact pro-environmental positive spillover over time (Clot et al., 2022). Misunderstandings around the relative environmental impact of certain actions may result in negative spillover (and therefore falsely equating certain behaviours as having an equal environmental cost).

Self-perception and self-identity are other key factors which can affect an individual's propensity for negative or positive spillover, with values such as pro-environmental identity extensively found to affect pro-environmental intention and behaviour (Whitmarsh and O'Neill, 2010; Brick and Lai, 2018). Self-efficacy has been examined as another mediator of spillover, with Lauren et al. (2016) specifically looking at this relationship from 'easy' to 'difficult' pro-environmental behaviours. They found that self-efficacy had a significant effect on intention and self-reported 'difficult' behaviours once an 'easy' behaviour had occurred. The relationship between positive and negative spillover mechanisms and constructing interventions is important, especially those which target high impact or more 'difficult' behaviours.

The complex interactions between and within pro-environmental behaviours within the framework of spillovers highlights the importance of considering pro-environmental behaviour holistically across domains in order to accurately account for a net pro-environmental behavioural outcome.

2.1.2.3 Psychological barriers

Barriers experienced by individuals have been previously categorised as individual/social barriers (Lorenzoni et al., 2007) and internal/external (Kollmuss and Agyeman, 2002). This research will focus on the internal, individual barriers which VR is assumed to overcome, which are often defined as psychological barriers to behaviour change. Psychological barriers (PBs) to pro-environmental behaviour are the internal processes which prevent new or changed behaviour occurring. Developing understanding around how psychological barriers work and manifest enables more effective interventions to be designed (Gifford et al., 2011). Psychological barriers are often explored in the context of a 'gap'

between behavioural determinants (e.g. knowledge and action, intention and action, concern and action) and behavioural outcomes (Lacroix et al., 2019).

There are several different ways of categorising psychological barriers to pro-environmental behaviour change. Psychological barriers can be factors such as lack of knowledge, habits, perceived distance of risk, distrust, and social norms (Lorenzoni et al., 2007) in addition to factors such as lack of self-efficacy and moral obligation as mentioned above. Gifford's (2011) categorisation of psychological barriers identifies seven broad principles (the ‘dragons of inaction’: limited cognition, ideologies, comparisons with others, sunk costs, discredence, perceived risks, and limited behaviour) that form general psychological barriers to change.

The framework designed by Kollmuss and Agyeman (2002) categorise barriers to change in a holistic way, by incorporating specific barriers into a model of change which is dynamic. Their model addresses reviews and critiques behavioural models (such as those outlined in 2.1.2), such as it considers how behavioural determinants interact in a dynamic and holistic way, and crucially, it centres the role of psychological barriers (‘blocks’), while being comprehensive yet usable. Gifford (2014, p553) recommends applying a theoretical model to pro-environmental behavioural research which “attend to the psychological barriers between concern and action”, which is addressed in the Kollmuss and Agyeman (2002) model. The Kollmuss and Agyeman (2002) model forms part of the theoretical grounding of this research, by forming the basis for the analytical framework in chapter 5, and the experimental design in chapter 6(see Figure 2). The external factors section of the model include structural determinants are not the focus of this work.

The Kollmuss and Agyeman (2002) model is chosen for this research, to apply but also interrogate it. The core concept and thread throughout this thesis is the exploration of psychological barriers, therefore the Kollmuss and Agyeman model was chosen for its inclusion and prominence of psychological barriers. Additionally, the holistic and non-linear representation of behavioural determinants and barriers addresses some of the critiques of the otherwise dominant theories across pro-environmental behavioural research. Van Valkengoed et al. (2022, p1483) identifies 5 core theoretical frameworks and

theories utilised across pro-environmental behavioural research ("the theory of planned behaviour (TPB), protection motivation theory (PMT), the norm activation model (NAM), value–belief–norm theory (VBN) and the focus theory of normative conduct (FTNC)"). These commons theories do not centre psychological barriers within their designs, making them less useful than the Kollmuss and Agyeman (2002) model to address these research questions. The COM-B model (Michie et al., 2011) has become a prominent model to apply to behavioural research since its creation and is a useful model for a range of disciplines (as it draws extensively from health sciences and psychology). However, in this case, the Kollmuss and Agyeman (2002) model is the most useful model to form the theoretical foundation and analytical framework of this research as it was designed for pro-environmental behaviour change specifically, and the psychological barriers explicitly identified within it can provide the baseline for the experimental design in chapter 6.

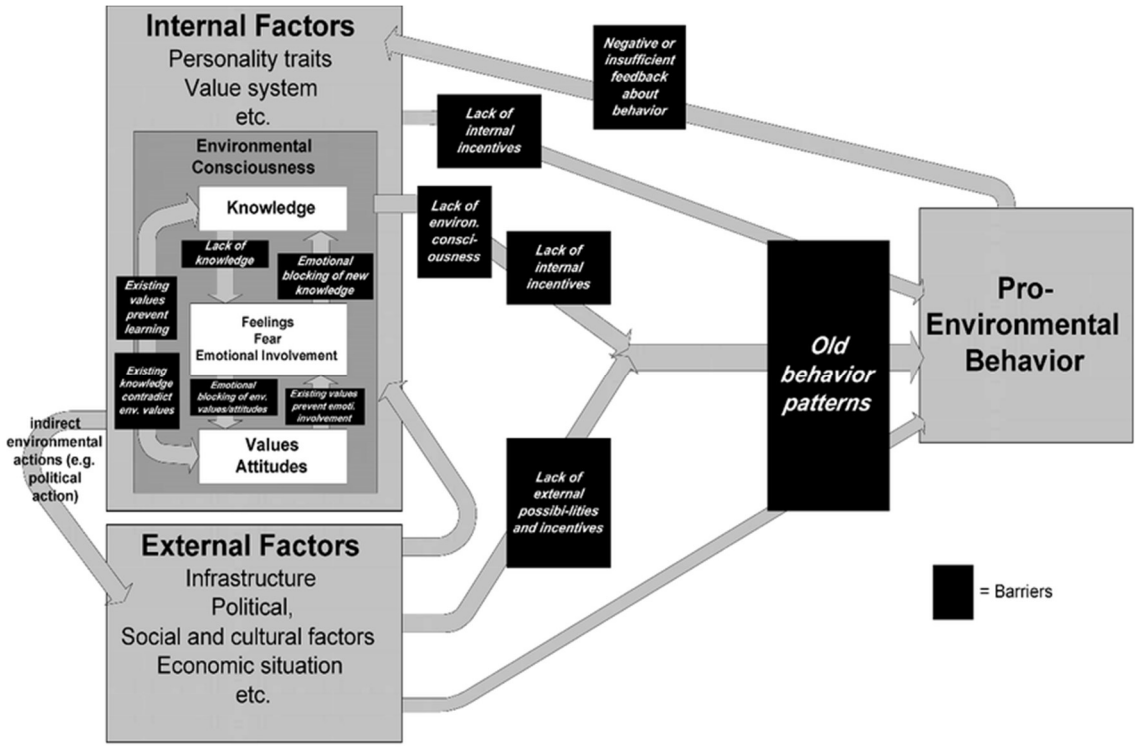


Figure 2 The Kollmuss and Agyeman (2002) model of pro-environmental behaviour

2.1.2.4 Psychological distance

The psychological distance (PD) associated with climate change and other environmental/ecological issues refers to the internal, and individual process that considers climate risk and impacts as distant (and therefore less relevant) to the individual. This can be divided into four manifestations of distance; geographical/spatial, temporal, societal and uncertainty (Spence and Pidgeon, 2010). Psychological Distance is a concept that has not yet been widely included in models of pro-environmental behaviour. Research has been increasingly incorporating psychological distance in pro-environmental behavioural studies and has been found to manifest in several interrelated ways. Psychological distance is based on the Construal Level Theory (Spence et al., 2012), and close distance perception and concrete mental construal of climate change were found to correlate with climate policy support (Chu, 2022).

There has been mixed evidence around the ubiquitous application or evidence for the role psychological distance can play in the behavioural process. Breves and Schramm (2021) found that environmental communications can manifest as ‘too close for comfort’ when those issues already are perceived as proximal. In Keller et al.'s (2022) systematic review of the literature around psychological distance and climate change, they identify that the impact of psychological distance is highly context dependent, and advocate for a more specific focus on the types of psychological distance. This indicates there may not be a ‘one size fits all’ understanding of this concept in behavioural interventions. Maiella et al. (2020, p. 12) found their systematic review of this literature showed that “*more pro-environmental and resilient behaviors are engaged through lower levels of psychological distance, the relationship between the two constructs is complex and still unclear*”.

Lorenzoni et al. (2007) specifically identify ‘future blindness’ as a barrier to engagement in climate change now, which indicates the importance of the temporal component in psychological distance. This is one example of where VR could provide a bridge by enabling visualisations of future scenarios, as visualisations of climate change can help to increase the relevance of the issue to the individual (Nicholson-Cole, 2005). Virtual Reality is a tool which is being widely used across communications and marketing within environmental

communications, as it is perceived to bring ‘distant’ issues such as climate change closer to the individual in a vivid, immersive way (Ballantyne et al., 2016; Gillath et al., 2008). The assumption here is that the ‘closer’ the experience (and therefore issue), the more likely a behavioural shift will occur. This will be measured in Phase 2 and 3 of the study through Spence et al.’s (2012) measure of psychological distance, as well as being the focus of the qualitative elements of the study in order to better understand how individuals perceive their own psychological distance. This will then be applied to the theoretical model of Kollmuss and Agyeman (2002) in order to include psychological distance (or its constituent parts) as a barrier to pro-environmental behaviour.

2.2 Communicating climate change

Communicating the causes, impacts, solutions, urgency, risk, and sometimes responsibilities associated with climate change to various audiences is a fundamental requirement of effective behaviour change. Climate communication comes in many forms, from targeted policy and public engagement campaigns by climate NGOs, to implicit normalisation of carbon-heavy lifestyles in traditional and social media. The information deficit model which previously dominated climate communications is now widely critiqued (Suldovsky, 2017), as a one-directional, narrow approach to communications and behaviour change. Alternative theoretical underpinnings have been found to be increasingly applied in practice, which are more focused on dialogue and deliberation within the creation and distribution of climate communications (Pearce et al., 2015; Moser, 2016; Kumpu, 2022). Other frameworks used to underpin climate change communications include risk communication and journalistic approaches (Evans et al., 2018), as well as increase in prominence of public engagement approaches (Ballantyne, 2016). An increase in ‘public engagement in science’ approaches has focused more on “minds, hearts and hands” (Wolf and Moser, 2011, p.550) as a framework for bridging the science-public interface through communications, which includes different types of audiences such as policymakers.

Despite an acknowledgement of the drawbacks of one-directional, linear climate communications, media communications are dominated by the assumption that provision of information translates to behaviour change. ‘Framing’ is a promising alternative and increasingly popular approach to climate communications (Nisbet, 2009). From a frame perspective, barriers (psychological or structural) were not identified explicitly in a systematic map of existing literature in (Badullovich et al., 2020), although there were themes associated with distance (geographic and uncertainty – related distance if aligned to the Spence et al. (2012) categorisation of psychological distance).

Considering the intersection of climate communications and pro-environmental behaviour theory and practice identifies the gaps and contradictions in how climate change is communicated to different audiences, as well as the opportunities for improvement. Using the Kollmuss and Agyeman (2002) model of pro-environmental behaviour change identifies key behavioural determinants, and crucially, barriers to behaviour change, which could provide a holistic theoretical grounding to construct climate change communications around.

2.2.1 Media and communicating climate change

The type of media used to communicate about climate change affects the audience reached, the message, and the impact it has. Research in this space has mainly focused on media representations of climate change (Schäfer and O’Neill, 2017), and Badullovich et al. (2020) found through a systematic map of the literature that analysis of news media was the most prominent type of study. Commonly, news and digital media continues to de-emphasise individual action (Seelig et al., 2022). Badullovich et al.’s recommendations align with Schäfer and O’Neill (2017) who suggest that research should broaden the media studied (beyond a reliance on print and news media) and the sources of media.

The research on the use of climate imagery in videos (through TV and film) has predominantly focused on news and documentary content (Graves and Morris, 2023). The use of TV and film as a communication medium is utilised by campaign organisations as well as creatives and storytellers, but the vast majority of climate content is explicitly focused on climate causes and impacts.

The impact of climate content through these media has been found to increase climate change awareness (Banchero et al., 2021), attitudes (Beattie and McGuire, 2020), and some small-scale, context-specific pro-environmental behaviours (Arendt and Matthes, 2016; Boissat et al., 2021).

Novel media (including sources of news) are increasingly visual, and present opportunities to engage audiences in different ways. In Wang et al.'s (2018) review of public engagement with visual climate communications they discuss how climate change is communicated to the public through different media. They identify a dearth of research around the visual imagery of climate change on social media. Social media is often touted as having the potential to democratise climate communications (Wang et al., 2018), which is supported by Olteanu et al. (2015) who found that about half of individual action content in relation to climate change events that featured prominently on twitter was created by non-elite users (neither rich, powerful or famous).

2.2.2 Virtual reality

Virtual reality presents an alternative to traditional media and an opportunity to overcome some of the barriers to behaviour change. Virtual reality can be used as an umbrella term for immersive technology, and colloquially, terms such as artificial reality (AR), extended reality (XR) and virtual reality (VR) are used interchangeably. Across different disciplines, these terms refer to subtly different technologies and experiences. This research understands VR to refer to a wholly immersive, 360° virtual environment, usually administered through a head mounted device (HMD). This is the type of virtual reality which is utilised for the experiment in Chapter 6, although this definition is broadened to include self-described VR (which may include AR and XR) in Chapter 4.

This research considers the use of VR from two perspectives, as a communication tool for pro-environmental behaviour, and it’s use as a research tool, therefore are outlined in turn.

2.2.2.1 VR as a communication tool

The primary assumption for the uses of virtual reality as a tool for climate change communication is its ability to bring distant issues and experiences closer to the individual, therefore overcoming psychological distance often associated with climate change. The behavioural assumption here is that this 'close' experience then impacts an individual's values, emotions (usually increasing empathy) or attitudes, which then translates to a change in behaviour.

From an experiential perspective, the effectiveness of virtual reality is dependent on four factors creating a viable and absorbing experience: presence, immersion, embodiment, and interaction (Martínez-Cano et al., 2023). These experiential and technological components of virtual reality experiences are discussed in more depth in Chapter 4, however it is worth noting that the research body is dominated by studies exploring the manipulation of these components.

The use of VR for communicating issues beyond environmental and climate issues can shed some light on the effectiveness of this medium. Martínez-Cano et al. (2023) recently published an excellent systematic review synthesis of VR - pro-social behaviour research. They identified that across the research body, issues such as emergency responsiveness, attitudes to race and ethnicity, terminal illness and refugees were examined. Sora-Domenjó (2022, p. 2) found that the most popular topics of non-fiction VR found on were "diaspora, refugee camps and exile".

There are examples of positive effects of VR on pro-social behaviours and behavioural determinants. Ahn et al. (2013) found that embodied experiences (i.e. the VR condition versus the non-immersive condition) increased 'helping behaviour', which included a component of empathy. Similarly, Bujić et al. (2020) found that pro-social attitudes (to human rights) were increased through VR, with the level of involvement within the VR experience affecting the degree of impact. Herrera et al. (2018) found that positive attitudes towards homelessness was increased and lasted longer in the VR condition compared

to a traditional perspective-taking exercise, when they had ‘experienced’ homelessness in VR.

Empathy is a common theme among VR research, and Breves (2020) found that the higher the immersiveness, the higher the parasocial empathy (i.e. empathy with the character in VR), however the impact on directly measured behaviour (donation behaviour) was mixed. Martingano et al. (2023) found similarly cautious results, where VR was found to increase social empathy (with child refugees), however this did not translate to directly measured behaviour (donations to a relevant charity (UNICEF)) and the effect on empathy returned to pre-test levels after 10 days. Sora-Domenjó (2022) argues for caution when advocating for the use of VR for pro-social purposes, due to the mixed evidence base, and ethical concerns raised in relation to VR research and practice.

Virtual reality has been found to increase engagement with education, learning and training, and aid decision making (Persky and McBride, 2009). Additionally, it “could improve environmental and risk communication, bring environmental issues psychologically closer, and influence the emotional and cognitive perceptions of users” (Buljat, 2022, p.45). VRs use as a communication tool has been well-examined in relation to certain questions such as the technological factors which impact the experience (e.g. presence and immersion). Research exploring its use for pro-social and pro-environmental purposes is still largely exploratory, and have centred on its use as an “empathy machine” (Milk, 2015).

2.2.2.2 VR as a research tool

The use of VR as a research tool is expanding, beyond the previously dominant areas of medicine and health, psychology and transport studies.

The purported benefits of VR as a research tool often include the ability to measure directly observed behaviour, as well as the ability to create difficult, dangerous or otherwise ethically problematic experiences within a safe space in VR. Measuring behaviour outside the laboratory, or over time, is logistically challenging and creates a tension between experimental control and ecological validity (Gillath et al., 2008). Ecological validity refers to the relevance of

research to ‘real life’ and “*everyday functionin*g” (Parsons, 2015, p.2). Applying virtual reality has been found to overcome existing methodological issues in behavioural psychology and improve “*experimental control, reproducibility, and ecological validity*” (Pan and Hamilton, 2018, p395). VR is used in research to manipulate variables and create scenarios (McCall and Blascovich, 2009) which may not otherwise be viable, safe or ethical to conduct. This therefore presents opportunities for pro-environmental behavioural research and both environmental psychology and social psychology more broadly.

2.3 Aims and objectives

This research brings the two areas of pro-environmental behaviour change and communicating climate change through virtual reality together. Virtual reality has been shown to present new opportunities for engagement with climate change and other sustainability stories, however little work has been done to test the assumptions that changes in empathy or attitudes leads to behaviour change. Additionally, the expectations that VR bridges the psychological distance felt between an individual and climate change, have also not been tested sufficiently. Finally, there is need for more work on the psychological barriers to pro-environmental behaviour change (and specifically psychological distance) as the mechanisms are highly context specific. This work focuses on psychological barriers to change due to the inherent assumptions around the use of VR for pro-environmental behaviour.

Therefore, the overarching aim of this research is to examine psychological barriers to pro-environmental behaviour change, with a focus on how virtual reality (VR) can be used to overcome them.

2.3.1 Research questions

This aim is explored in three phases, with three primary research questions structuring each phase.

Phase 1. How has virtual reality been used to research pro-environmental behaviour?

Phase 2. What role do psychological barriers play in the pro-environmental behaviour change mechanism?

Phase 3. Can psychological barriers to pro-environmental behaviour change be overcome through VR?

Phase 1 provides the grounding to the subsequent research questions and research design, with a systematic literature review exploring the existing evidence around virtual reality and pro-environmental behaviour change. Phase 2 focuses on the psychological barriers to a key, high-impact behaviour (meat consumption) and explores this through a rapid evidence review. Phase 3 brings these two components together in an experimental design to test how an environmental-themed VR experience impacts pro-environmental behavioural determinants, and crucially, barriers.

2.4 References

Ahn, S.J., Le, A.M.T. and Bailenson, J. 2013. The Effect of Embodied Experiences on Self-Other Merging, Attitude, and Helping Behavior. Media Psychology. 16(1), pp.7–38.

Ajzen, I. 1991. The Theory of Planned Behavior In: Organizational Behavior and Human Decision Processes., pp.179–211.

Arendt, F. and Matthes, J. 2016. Nature Documentaries, Connectedness to Nature, and Pro-environmental Behavior. Environmental Communication. 10(4), pp.453–472.

Badullovich, N., Grant, W.J. and Colvin, R.M. 2020. Framing climate change for effective communication: a systematic map. Environmental Research Letters. 15(12), p.123002.

Ballantyne, A.G. 2016. Climate change communication: what can we learn from communication theory? WIREs Climate Change. 7(3), pp.329–344.

Ballantyne, A.G., Wibeck, V. and Neset, T.-S. 2016. Images of climate change – a pilot study of young people's perceptions of ICT-based climate visualization. Climatic Change. 134(1–2), pp.73–85.

Banchero, P., Rector, T.A. and Van Ballenberghe, J. 2021. Best practices in climate change communication as applied to an informal education documentary about Alaska. Journal of Geoscience Education. 69(2), pp.138–149.

Barr, S., Gilg, A.W. and Ford, N. 2005. The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. Energy Policy. 33(11), pp.1425–1444.

Beattie, G. and McGuire, L. 2020. The Modifiability of Implicit Attitudes to Carbon Footprint and Its Implications for Carbon Choice. Environment and Behavior. 52(5), pp.467–494.

Boissat, L., Thomas-Walters, L. and Veríssimo, D. 2021. Nature documentaries as catalysts for change: Mapping out the 'Blackfish Effect'. People and Nature. 3(6), pp.1179–1192.

Breves, P. 2020. Bringing People Closer: The Prosocial Effects of Immersive Media on Users' Attitudes and Behavior. Nonprofit and Voluntary Sector Quarterly. 49(5), pp.1015–1034.

Breves, P. and Schramm, H. 2021. Bridging psychological distance: The impact of immersive media on distant and proximal environmental issues. Computers in Human Behavior. 115, p.106606.

Brick, C. and Lai, C.K. 2018. Explicit (but not implicit) environmentalist identity predicts pro-environmental behavior and policy preferences. Journal of Environmental Psychology. 58, pp.8–17.

Bujić, M., Salminen, M., Macey, J. and Hamari, J. 2020. "Empathy machine": how virtual reality affects human rights attitudes. Internet Research. 30(5), pp.1407–1425.

Buljat, B. 2022. Environmental policy and immersive technologies. Journal of Behavioral Economics for Policy. 6(Special Issue 1), pp.41–47.

Capstick, S., Whitmarsh, L.E., Nash, N.C., Haggar, P. and Lord, J. 2019. Compensatory and catalysing behavioural beliefs: Development and psychometric properties of an instrument for measuring spillover-related perceptions in seven countries. Frontiers in Psychology. 10.

Chiou, W.-B., Wan, C.-S., Wu, W.-H. and Lee, K.-T. 2011. A randomized experiment to examine unintended consequences of dietary supplement use among daily smokers: taking supplements reduces self-regulation of smoking. Addiction. 106(12), pp.2221–2228.

Chu, H. 2022. Construing Climate Change: Psychological Distance, Individual Difference, and Construal Level of Climate Change. Environmental Communication. 0(0), pp.1–17.

Clot, S., Della Giusta, M. and Jewell, S. 2022. Once Good, Always Good? Testing Nudge's Spillovers on Pro Environmental Behavior. Environment and Behavior. 54(3), pp.655–669.

DEFRA and Pow, R. 2021. 10p plastic bag charge introduced in England. [Accessed 31 March 2023]. Available from:

https://www.gov.uk/government/news/10p-plastic-bag-charge-introduced-in-england.

Dolan, P. and Galizzi, M.M. 2015. Like ripples on a pond: Behavioral spillovers and their implications for research and policy. Journal of Economic Psychology. 47, pp.1–16.

Evans, H.-C., Dyll, L. and Teer-Tomaselli, R. 2018. Communicating Climate Change: Theories and Perspectives In: W. Leal Filho, E. Manolas, A. M. Azul, U. M. Azeiteiro and H. McGhie, eds. Handbook of Climate Change Communication: Vol. 1 [Online]. Climate Change Management. Cham: Springer International Publishing, pp.107–122. [Accessed 1 November 2023]. Available from: http://link.springer.com/10.1007/978-3-319-69838-0_7.

Fox, J., McKnight, J., Sun, Y., Maung, D. and Crawfis, R. 2020. Using a serious game to communicate risk and minimize psychological distance regarding environmental pollution. Telematics and Informatics. 46.

Gatersleben, B. 2023. Chapter 7: Measuring pro-environmental behaviour: a critical reflection In: Handbook on Pro-Environmental Behaviour Change [Online]. Cheltenham, UK: Edward Elgar Publishing, pp.114–124. [Accessed 16 August 2024]. Available from: https://www.elgaronline.com/edcollchap/book/9781800882133/book-part-9781800882133-15.xml.

Gifford, R. 2006. A general model of social dilemmas. International Journal of Ecological Economics & Statistics. 4(S06).

Gifford, R. 2011. The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. American Psychologist. 66(4), pp.290–302.

Gifford, R., Kormos, C. and McIntyre, A. 2011. Behavioral dimensions of climate change: drivers, responses, barriers, and interventions: Behavioral dimensions of climate change. Wiley Interdisciplinary Reviews: Climate Change. 2(6), pp.801–827.

Gifford, R. 2014. Environmental Psychology Matters. Annual Review of Psychology. 65(1), pp.541–579.

Gifford, R.D. and Chen, A.K.S. 2017. Why aren't we taking action? Psychological barriers to climate-positive food choices. Climatic Change. 140(2), pp.165–178.

Gillath, O., McCall, C., Shaver, P.R. and Blascovich, J. 2008. What can virtual reality teach us about prosocial tendencies in real and virtual environments? Media Psychology. 11(2), pp.259–282.

Glanz, K., Bader, M.D.M. and Iyer, S. 2012. Retail Grocery Store Marketing Strategies and Obesity: An Integrative Review. American Journal of Preventive Medicine. 42(5), pp.503–512.

Gómez-Donoso, C., Sacks, G., Vanderlee, L., Hammond, D., White, C.M., Nieto, C., Bes-Rastrollo, M. and Cameron, A.J. 2021. Public support for healthy supermarket initiatives focused on product placement: a multi-country cross-sectional analysis of the 2018 International Food Policy Study. International Journal of Behavioral Nutrition and Physical Activity. 18(1), p.78.

Graves, C. and Morris, L. 2023. The impact of climate content on audiences' pro-environmental behaviour [Online]. London: BAFTA albert Ltd. Available from: https://wearealbert.org/climate-content-audience-insights/.

Grilli, G. and Curtis, J. 2021. Encouraging pro-environmental behaviours: A review of methods and approaches. Renewable and Sustainable Energy Reviews. 135, p.110039.

Hampton, S. and Adams, R. 2018. Behavioural economics vs social practice theory: Perspectives from inside the United Kingdom government. Energy Research & Social Science. 46, pp.214–224.

Haq, G., Cambridge, H. and Owen, A. 2013. A targeted social marketing approach for community pro-environmental behavioural change. Local Environment. 18(10), pp.1134–1152.

Herrera, F., Bailenson, J., Weisz, E., Ogle, E. and Zaki, J. 2018. Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. PLOS ONE. 13(10).

Herring, H. and Sorrell, S. 2009. Energy Efficiency and Sustainable Consumption - The Rebound Effect [Online]. Palgrave Macmillan UK.

[Accessed 20 May 2019]. Available from: https://www.palgrave.com/gp/book/9780230525344.

Involve 2010. Nudge, think or shove? Shifting values and attitudes towards sustainability. DEA.

Ivanova, D., Barrett, J., Wiedenhofer, D., Macura, B., Callaghan, M. and Creutzig, F. 2020. Quantifying the potential for climate change mitigation of consumption options. Environmental Research Letters. 15(9), p.093001.

Jensen, B.B. 2002. Knowledge, Action and Pro-environmental Behaviour. Environmental Education Research. 8(3), pp.325–334.

Keller, E., Marsh, J.E., Richardson, B.H. and Ball, L.J. 2022. A systematic review of the psychological distance of climate change: Towards the development of an evidence-based construct. Journal of Environmental Psychology. 81, p.101822.

Kemper, J.A. 2020. Motivations, barriers, and strategies for meat reduction at different family lifecycle stages. Appetite. 150.

Klöckner, C.A. 2013. A comprehensive model of the psychology of environmental behaviour—A meta-analysis. Global Environmental Change. 23(5), pp.1028–1038.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research. 8(3), pp.239–260.

Kumpu, V. 2022. What is Public Engagement and How Does it Help to Address Climate Change? A Review of Climate Communication Research. Environmental Communication. 16(3), pp.304–316.

Lacroix, K., Gifford, R. and Chen, A. 2019. Developing and validating the Dragons of Inaction Psychological Barriers (DIPB) scale. Journal of Environmental Psychology. 63, pp.9–18.

Lange, F. and Dewitte, S. 2019. Measuring pro-environmental behavior: Review and recommendations. Journal of Environmental Psychology. 63, pp.92–100.

Larson, L.R., Stedman, R.C., Cooper, C.B. and Decker, D.J. 2015. Understanding the multi-dimensional structure of pro-environmental behavior. Journal of Environmental Psychology. 43, pp.112–124.

Lauren, N., Fielding, K.S., Smith, L. and Louis, W.R. 2016. You did, so you can and you will: Self-efficacy as a mediator of spillover from easy to more difficult pro-environmental behaviour. Journal of Environmental Psychology. 48, pp.191–199.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. Global Environmental Change. 17(3–4), pp.445–459.

Maiella, R., La Malva, P., Marchetti, D., Pomarico, E., Di Crosta, A., Palumbo, R., Cetara, L., Di Domenico, A. and Verrocchio, M.C. 2020. The Psychological Distance and Climate Change: A Systematic Review on the Mitigation and Adaptation Behaviors. Frontiers in Psychology. 11.

Maki, A., Carrico, A.R., Raimi, K.T., Truelove, H.B., Araujo, B. and Yeung, K.L. 2019. Meta-analysis of pro-environmental behaviour spillover. Nature Sustainability. 2(4), pp.307–315.

Martínez-Cano, F.-J., Lachman, R. and Canet, F. 2023. VR content and its prosocial impact: predictors, moderators, and mediators of media effects. A systematic literature review. Frontiers in Communication. 8, p.1203242.

Martingano, A.J., Konrath, S., Henritze, E. and Brown, A.D. 2023. The Limited Benefits of Using Virtual Reality 360° Videos to Promote Empathy and Charitable Giving. Nonprofit and Voluntary Sector Quarterly. 52(5), pp.1434–1457.

McCall, C. and Blascovich, J. 2009. How, When, and Why to Use Digital Experimental Virtual Environments to Study Social Behavior. Social and Personality Psychology Compass. 3(5), pp.744–758.

Michie, S., van Stralen, M.M. and West, R. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science : IS. 6, p.42.

Milk, C. (2015). How virtual reality can create the ultimate empathy machine [video file]. https://www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_ empathy_machine/transcript

Moser, S.C. 2016. Reflections on climate change communication research and practice in the second decade of the 21st century: what more is there to say? WIREs Climate Change. 7(3), pp.345–369.

Nash, N., Whitmarsh, L., Capstick, S., Hargreaves, T., Poortinga, W., Thomas, G., Sautkina, E. and Xenias, D. 2017. Climate-relevant behavioral spillover and the potential contribution of social practice theory. WIREs Climate Change. 8(6), p.e481.

Nicholson-Cole, S.A. 2005. Representing climate change futures: a critique on the use of images for visual communication. Computers, Environment and Urban Systems. 29(3), pp.255–273.

Nisbet, M.C. 2009. Communicating Climate Change: Why Frames Matter for Public Engagement. Environment. 51(2), pp.12–23.

Olteanu, A., Castillo, C., Diakopoulos, N. and Aberer, K. 2015. Comparing Events Coverage in Online News and Social Media: The Case of Climate Change. Proceedings of the International AAAI Conference on Web and Social Media. 9(1), pp.288–297.

O'Neill, D.W., Fanning, A.L., Lamb, W.F. and Steinberger, J.K. 2018. A good life for all within planetary boundaries. Nature Sustainability. 1(2), pp.88–95.

Pan, X. and Hamilton, A.F. de C. 2018. Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. British Journal of Psychology. 109(3), pp.395–417.

Parsons, T.D. 2015. Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. Frontiers in Human Neuroscience. 9.

Pearce, W., Brown, B., Nerlich, B. and Koteyko, N. 2015. Communicating climate change: conduits, content, and consensus. WIREs Climate Change. 6(6), pp.613–626.

Persky, S. and McBride, C.M. 2009. Immersive Virtual Environment Technology: A Promising Tool for Future Social and Behavioral Genomics Research and Practice. HEALTH COMMUNICATION. 24(8), pp.677–682.

Poortinga, W., Steg, L. and Vlek, C. 2004. Values, Environmental Concern, and Environmental Behavior: A Study into Household Energy Use. Environment and Behavior. 36(1), pp.70–93.

Rosa, C.D. and Collado, S. 2020. Enhancing Nature Conservation and Health: Changing the Focus to Active Pro-environmental Behaviours. Psychological Studies. 65(1), pp.9–15.

Schäfer, M.S. and O'Neill, S. 2017. Frame Analysis in Climate Change Communication: Approaches for Assessing Journalists' Minds, Online Communication and Media Portrayals In: M. Nisbet, S. Ho, E. Markowitz, S. O'Neill, M. S. Schäfer and J. Thaker, eds. Schäfer, Mike S; O'Neill, Saffron (2017). Frame Analysis in Climate Change Communication: Approaches for Assessing Journalists' Minds, Online Communication and Media Portrayals. In: Nisbet, Matthew; Ho, Shirley; Markowitz, Ezra; O'Neill, Saffron; Schäfer, Mike S; Thaker, Jagadish. Oxford Encyclopedia of Climate Change Communication. New York: Oxford University Press, n/a. [Online]. New York: Oxford University Press, n/a. [Accessed 9 November 2023]. Available from: http://climatescience.oxfordre.com/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-487.

Seelig, M.I., Deng, H. and Liang, S. 2022. A frame analysis of climate change solutions in legacy news and digital media. Newspaper Research Journal. 43(4), pp.370–388.

Siegel, L., Cutter-Mackenzie-Knowles, A. and Bellert, A. 2018. Still 'Minding the Gap' Sixteen Years Later: (Re)Storying Pro-Environmental Behaviour. Australian Journal of Environmental Education. 34(2), pp.189–203.

Sora-Domenjó, C. 2022. Disrupting the "empathy machine": The power and perils of virtual reality in addressing social issues. Frontiers in Psychology. 13.

Spence, A. and Pidgeon, N. 2010. Framing and communicating climate change: The effects of distance and outcome frame manipulations. Global Environmental Change. 20(4), pp.656–667.

Spence, A., Poortinga, W. and Pidgeon, N. 2012. The Psychological Distance of Climate Change. Risk Analysis. 32(6), pp.957–972.

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A. and Kalof, L. 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review. 6(2), p.17.

Stern, P.C. 2000. New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior. Journal of Social Issues. 56(3), pp.407–424.

Stern, P.C. 2020. A reexamination on how behavioral interventions can promote household action to limit climate change. *Nature Communications*. **11**(1), p.918.

Suldovsky, B. 2017. The Information Deficit Model and Climate Change Communication In: Oxford Research Encyclopedia of Climate Science [Online]. [Accessed 1 November 2023]. Available from: https://oxfordre.com/climatescience/climatescience/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-301.

Thaler, R. and Sunstein, C. 2008. Nudge: Improving decisions about health, wealth, and happiness. New Haven, CT: Yale University Press.

Thøgersen, J. and Noblet, C. 2012. Does green consumerism increase the acceptance of wind power? Energy Policy. 51, pp.854–862.

Thøgersen, J. and Ölander, F. 2006. To What Degree are Environmentally Beneficial Choices Reflective of a General Conservation Stance? Environment and Behavior. 38(4), pp.550–569.

Tyers, R. 2018. Nudging the jetset to offset: voluntary carbon offsetting and the limits to nudging. *Journal of Sustainable Tourism*. **26**(10), pp.1668–1686.

Van Boven, L., Kane, J., McGraw, A.P. and Dale, J. 2010. Feeling close: Emotional intensity reduces perceived psychological distance. Journal of Personality and Social Psychology. 98(6), pp.872–885.

Van Valkengoed, A.M., Abrahamse, W. and Steg, L. 2022. To select effective interventions for pro-environmental behaviour change, we need to consider determinants of behaviour. Nature Human Behaviour. 6(11), pp.1482–1492.

Verplanken, B. and Roy, D. 2016. Empowering interventions to promote sustainable lifestyles: Testing the habit discontinuity hypothesis in a field experiment. Journal of Environmental Psychology. 45, pp.127–134.

Wang, S., Corner, A., Chapman, D. and Markowitz, E. 2018. Public engagement with climate imagery in a changing digital landscape. Wiley Interdisciplinary Reviews: Climate Change. 9(2), p.e509.

Welch, D. 2017. Behaviour change and theories of practice: Contributions, limitations and developments. Social Business. 7(3), pp.241–261.

Whitmarsh, L. and O'Neill, S. 2010. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. Journal of Environmental Psychology. 30(3), pp.305–314.

Wi, A. and Chang, C.-H. 2019. Promoting pro-environmental behaviour in a community in Singapore – from raising awareness to behavioural change. Environmental Education Research. 25(7), pp.1019–1037.

Wolf, J. and Moser, S.C. 2011. Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. WIREs Climate Change. 2(4), pp.547–569.

Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environmental Research Letters. 12(7), p.074024.

Chapter 3 Methods

3.1 Research framework

This work brings together disparate disciplines across environmental psychology, behavioural science, media and communications and often tussles with exploring social science questions with psychological methods, and vice versa. Therefore, it is useful to outline how the key concepts, questions and crucially, methods, fit together. Additionally, the impact of Covid-19 is outlined due to its significant impact on the thinking and practicalities of this work.

This work brings together several key areas; sustainability (primarily climate change), behavioural theory, behavioural interventions, and virtual reality (as a communication tool). From a disciplinary perspective, this work sits between environmental social sciences and environmental psychology. Chapter 1 situates the challenges associated with climate change and the need for individuals to act in order to reach international and national climate policies, therefore here I outline how these issues translate into research questions and the approach taken to answer these questions.

In this research I primarily apply a pragmatist approach. Through this, I have chosen the research design and methods which I feel best suits the research questions (Creswell and Creswell, 2018). My approach has moved further away from a positivist approach through the process of conducting this research, due to level of methodological criticality which emerged organically, especially during Phase 1.

I apply a mixed methods approach due to this underpinning approach to research. In the original, pre-Covid research plan, Phase 3 involved follow-up interviews with participants to explore their perception of the VR experience and their own behaviour. In the adapted research design, I integrated qualitative elements into an otherwise predominantly quantitative approach within the experiment.

A concept which I believe is important to address is the fundamental normative assumption present throughout this research that individuals ‘should’ change their behaviour in order to reduce their environmental impact. I want to

acknowledge that I do believe most people, especially within the UK and other global north countries, could reduce their environmental impact, there are justice and fairness implications. I think the work around co-benefits of pro-environmental behaviour change presents opportunities to address issues of public health, infrastructure access and inequality, to ensure a just transition.

Additionally, it is important to note that this work on individual level behaviour change should sit within a larger infrastructure and system-wide change to mitigate climate change and environmental degradation. The current ongoing debates in environmental psychology (e.g. Lange et al., 2021, Nielsen et al., 2021, van Valkengoed et al., 2021) around impact vs. theory include intrinsic discussion around individual vs. systemic change. The narrative of individual vs. system change is something I avoid wherever possible, as I feel it is broadly unhelpful and sometimes counter-productive to the overall impact and ambition of research in this space. One grounding principle of this research is that individual and system change should be explored symbiotically and that both are essential for a meaningful, just transition.

Phase	Research Question	Method	Output
1. How has virtual reality been used to research pro-environmental behaviour?	RQ1: How has virtual reality been found to affect pro-environmental behaviour?	Systematic review	'Virtual reality and pro-environmental behaviour: a systematic review'
	RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?		
	RQ3: How is behavioural theory applied across pro-environmental behavioural change research which utilises virtual reality?		
2. What role do psychological barriers have in the pro-environmental behaviour change mechanism?	RQ4: How can psychological barriers to pro-environmental behaviour change affect meat consumption in individuals?	Rapid evidence review	'Bridge the gap': a rapid evidence review of psychological barriers to reducing meat consumption. (published; Sustainability, October 2021)
	RQ5: How does Psychological Distance manifest as a barrier to meat consumption reduction?		
	RQ6: How can these psychological barriers be overcome?		
3. Can psychological barriers to pro-environmental behaviour change be overcome through VR?	RQ7: What are the behavioural effects of an environmental VR intervention over time?	Experimental design	'The effect of a climate change virtual reality experience on pro-environmental behaviour'
	RQ8: What are the effects of an environmental VR intervention on psychological distance?		

Table 1 Table of research questions and methods

Phase 1 identifies several conceptual and methodological areas for further research, which Phase 3 aims to build on. VR was found to have added value in previous studies, however these were dominated by very small-scale, low impact behaviours, over a limited time series, with minimal external validity.

Phase 2 identifies that psychological barriers to behaviour change can work in three ways (within the specific, high impact behavioural domain of meat consumption), which are; direct barriers (knowledge, values etc.), barriers as gaps between behavioural determinants (i.e. a broken link between knowledge and values), and barriers as gaps between perception and behaviour.

Phase 3 brings these two sets of findings together, by testing a VR-based intervention and measuring the impact on pro-environmental behavioural determinants and psychological barriers over time through a field experiment. It focusses on a range of high impact behaviours to explore pro-environmental behaviour holistically, including an element on the animal-self connection (connection to nature) to relate directly to Phase 2. Phase 3 was designed to address both empirical and methodological questions raised in Phase 1. The qualitative elements will focus on building on the conceptual findings in Phase 2 around psychological barriers to behaviour change.

3.2 Phase 1

Phase 1 aimed to identify what pro-environmental behavioural determinants and outcomes have been measured or tested using VR, in order to identify commonalities and research gaps to feed into the research design of Phase 2&3. The systematic review aimed to provide the grounding and justification for the research project, by generating a comprehensive picture of the research landscape. The use of a systematic review was chosen due to the disparate nature of the concepts and the novelty of the research, which a systematic review can mitigate for by ensuring comprehensive coverage across disciplines and lexicons.

3.2.1 Research questions

Overarching RQ: How has virtual reality been used to research pro-environmental behaviour?

- RQ1: How is behavioural theory applied across pro-environmental behavioural change research which utilises virtual reality?
- RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?
- RQ3: How has virtual reality been found to affect pro-environmental behaviour?

3.2.1.1 Systematic reviews overview: critical reflections

Systematic reviews are considered the ‘gold standard’ of literature review (O’Leary et al., 2017). However, the requirements for what constitutes a systematic review varies widely between and across disciplines. Systematic reviews originated from the rigour required within medical and health research, which led to the formation of the Cochrane Collaboration (a standardised platform and system for systematic reviews). The Cochrane principles can be applied to other disciplines and have been followed by platforms and systems such as the Campbell Collaboration, and more recently the Collaboration for Environmental Evidence (Woodcock et al., 2014).

There is disparity outside of the medical and health disciplines over the use of different types of systematic review and the definitions of each. Systematic reviews range from rigorous, highly structured formats with protocols which are registered with either the Cochrane or Campbell collaborations, to closer to traditional narrative literature reviews conducted in a pre-determined way (with or without pre-registration). Systematic reviews in medicine and health centre on the need to evaluate systematically the literature around one singular or suite of similar 'interventions'. These are predominantly quantitative assessments, assimilated and analysed systematically (often through meta-analysis) in order to identify the state of current knowledge about the effectiveness of an intervention (O'Leary et al., 2016). More recently, systematic reviews have been widely utilised to assess social policy and are often the basis for government reports. Again, this uses the concept of the 'intervention' (i.e. a specific policy) and synthesises the research in order for the reader to draw conclusions and recommendations from the full body of literature (Gough and Elbourne, 2002).

Using systematic reviews in areas beyond medicine and health is increasing, and the definitions for what constitutes a 'systematic review' should be broadened in order to enable rigorous approaches to synthesis to be applicable to different disciplines and questions. Applying systematic reviews to an environmental social science context presents challenges due to the often interdisciplinary nature of the studies, and the difficulty in applying a systematic methodology historically built on quantitative data (in medicine and health) to qualitative or mixed methods data. However, approaches such as narrative synthesis (Popay et al., 2006) and realist and meta-narrative syntheses (Greenhalgh et al., 2011) provide options for synthesis within systematic reviews. There is significant disparity around what constitutes a systematic review beyond the broad requirements of replicability, rigor and critical analysis. Outside the health disciplines, and especially within qualitative socio-environmental research, conducting a 'systematic review' can mean very different things conceptually and methodologically. There are several principles of systematic reviews which have been identified as areas of debate, often due to these disciplinary and cross-disciplinary differences:

1. The requirement for protocols to be registered on a platform prior to review being conducted. Although this is common practice with the Cochrane Collaboration, this may be unfeasible for qualitative work, interdisciplinary work or novel areas which may require more iteration (Haddaway and Bilotta, 2016).

2. The number of reviewers systematic reviews require. The assumption that more than one is required was argued not to be the case by Boland et al. (2017) despite this being a key feature of the majority of reviews evaluated. This may be due to Boland et al.'s (2017) focus on research using student participants, and the logistical difficulties often faced through this.

3. The level of iteration suitable for a systematic review. The degree to which protocols can be amended, and at what point, with what process is highly variable.

4. Coverage versus saturation. The literature coverage is a key area of contention, which is largely determined by the research question posed (Snape et al., 2017), and a precise research question is the key to a useful review (Gough and Elbourne, 2002). A key component to identify is the 'stopping point' for literature searching. The depth to which reviewers searched databases varies widely, and a clear indication for when conceptual coverage is reached is difficult to pre-define when exploring multi-faceted or broad research questions.

5. Methodological clarity of synthesis from the outset, and the implications for replicability. The level of detail provided for the search strategy tends to be extensive, with less emphasis on synthesis and analysis methods.

There are a number of principles of systematic reviews which distinguish it from other synthesis methodologies, which can apply to the context of a broad social science research question:

1. Methods should be clear enough to be repeatable (Haddaway and Bilotta, 2016; Snape et al., 2017). A key feature of systematic reviews is the transparency; where the reader is able to assess and evaluate how conclusions are reached (Gough and Elbourne, 2002).

2. The relevant literature needs to be searched for and analysed in a systematic way (Haddaway and Bilotta, 2016). Early scoping and piloting the searching strategy can help avoid iteration later in the process.

3. Quality assessment is essential for a true critical appraisal (Gough and Elbourne, 2002; Haddaway et al., 2015; Haddaway and Bilotta, 2016).

4. The protocol needs to be outlined prior to conducting the review. If changes are made, they need to be explicitly outlined and justified.

5. The key to a useful and rigorous systematic review are clear research questions, and specific inclusion and exclusion sifting criteria to determine boundaries of included studies (Snape et al., 2017).

Taking the core principles above and considering logistical issues (e.g. timeframes, interdisciplinary approach, novelty of research area) in the context of the points of debate above result in identifying a more iterative process as more appropriate for this project. This is combined with a systematically comprehensive approach for the search strategy, akin to the methods of Sorrell (2007).

3.2.2 Methods

This systematic review aimed to explore the existing body of work conducted around pro-environmental behaviour change (PEBC) using virtual reality (VR). This exploration of the methodology and outcomes is synthesised through a narrative synthesis, due to the disparate nature of the studies and findings.

This systematic review was conducted in two phases, with the first phase of data collection and analysis occurring in 2018, and the repeated phase

occurring in 2020, with the searches focusing on work published 2010-2020, in order to balance comprehensiveness with practicality. The protocol was developed in accordance with the guidance provided in the Collaboration for Environmental Evidence Synthesis Assessment Tool guidelines (Woodcock et al., 2014) in addition to Boland et al. (2017), Haddaway and Bilotta (2016), EPPI-Centre (2003), and Petticrew and Roberts (2006) (Appendix A).

3.2.2.1 Exclusion/inclusion criteria

In line with the standardised PICOS framework (Haddaway et al., 2015), inclusion and exclusion criteria were developed from the research questions Table 2. These were developed prior to conducting the searches, however iteration did occur post-scoping searches, in order to better reflect the terminology used across disciplines.

	Inclusion	***Exclusion***
Language	English language only	Non-English language
Publication date	No date restrictions	No date restrictions
Databases	Academic literature: SCOPUS, Web of science, EBSCOhost (conference proceedings, academic publications), PsycINFO. Additional: Google Scholar	
Methodology	Primary quantitative and qualitative studies.	Review studies
	VR used in methodology as the intervention or tool.	
	Extended reality methods applied should be explicitly immersive, i.e. headset or other immersive technology. Must explicitly be IVET (immersive virtual environment technology). Terminology generally which will indicate suitable technology/level of immersion: XR/Extended reality, Immersive technology, virtual reality.	'Virtual environments' including computer-based screens, online games and other online platforms.

Conceptual	Literature needs to address change in attitudes, values, intentions or behaviour (including the whole spectrum of behaviour including empathy, presence, awareness, education, intent to act, actions, long term change).	Behaviour change which does not relate to societal concepts/issues (i.e. physiological effects, treatment of disease or training/learning development)
	Explicit use of environmental issues as the context for behavioural study. This could be methodologically explicit, or discussed conceptually. This could also include behaviours which affect environmental issues indirectly, but the link needs to be explicitly made.	Medical literature (e.g. neuroscience or physiological effects of VR). Engineering/computing literature with no human/social element.
	Human behavioural study in any society/geography and at any scale (individual and social).	
Participants/scope		Non-human subjects

Table 2 Inclusion / exclusion criteria for systematic review

3.2.2.2 Scoping search

A scoping study was required to develop relevant search strings for the systematic review. This was conducted using broad terms relating to virtual reality and pro-environmental behaviour, using both Scopus and Web of Science (i.e. Scopus: (TITLE-ABS-KEY ("virtual reality" OR "immersive environment" OR "augmented reality") AND TITLE-ABS-KEY ("Environment* behavio*"))). This identified that a range of specific search strings would need to be created which focused on different elements of pro-environmental behavioural change. These concept-specific searches enabled a comprehensive approach and coverage. Initial searches identified key papers (n=8) which were used to build a concept map to develop the search strategy around. This concept map can be condensed into: virtual reality (virtual reality, VR, immersive virtual environment, IVE, immersive virtual reality, virtual environments), intervention terminology (experiment, tool, intervention), behavioural concepts (beliefs, values, behavioural intentions, attitudes, knowledge), and environment focused (environment; climate change; sustainability).

3.2.2.3 Search strategy

Search strings were trialled and adapted based on relevance of results; for instance ‘virtual environment’ was removed due to high frequency of literature on physiological effects of computer usage. The results from the full searches were sense-checked by ensuring the 8 key articles appear in the results, in addition to checking against bibliographies of key authors (Ahn, Bailenson and Blascovich). Citation searches of these key papers were then undertaken to ensure that relevant literature was captured in database searches. These were downloaded into Zotero. After the initial searches were conducted, they were repeated (late January 2019 and again in October 2020) in order to capture the most recent publications and records. These were downloaded and compiled in Zotero, and once duplicates were removed, 3371 unique records were held in the database.

3.2.2.4 Data collection

An initial sift of the title and abstract was undertaken with the application of a broad interpretation of the inclusion/exclusion criteria (**Table 2**). Each record was analysed for the presence of the three key concepts of the review; environmental issues, utilising virtual reality technology (e.g. head-mounted devices, augmented reality games, immersive cinema) and measurement of pro-environmental behaviour change as an outcome (empathy, presence, awareness, action, intent to act, values (and related concepts/synonyms)). After the primary reviewer (CG) had conducted the first sift, the second reviewer (KR) sifted 10% of the database. This was conducted by assigning a random number generator to each record and selecting the top 10%. There were two records where the second reviewer categorised the records differently to the primary reviewer. These were discussed and final decisions were agreed (date 4/2/19). This was below the 10% disagreement threshold therefore the protocol was agreed to be effective, and the second sift could commence. There were 85 records included and 1917 records were excluded based on a title and abstract assessment. The second sift was then conducted and involved full text analysis using the inclusion/exclusion criteria. The second reviewer sampled 10% of the 85 included records. The full text analysis of the 9 articles produced no discrepancy with the primary reviewer. The full text analysis resulted in a total of 13 records included, with 68 records excluded based on the criteria (see Figure 3). The same searches were re-run in October 2020 with sifting conducted in line with the method above, with 651 new records and 5 included in the final sift, totalling 18 records overall.

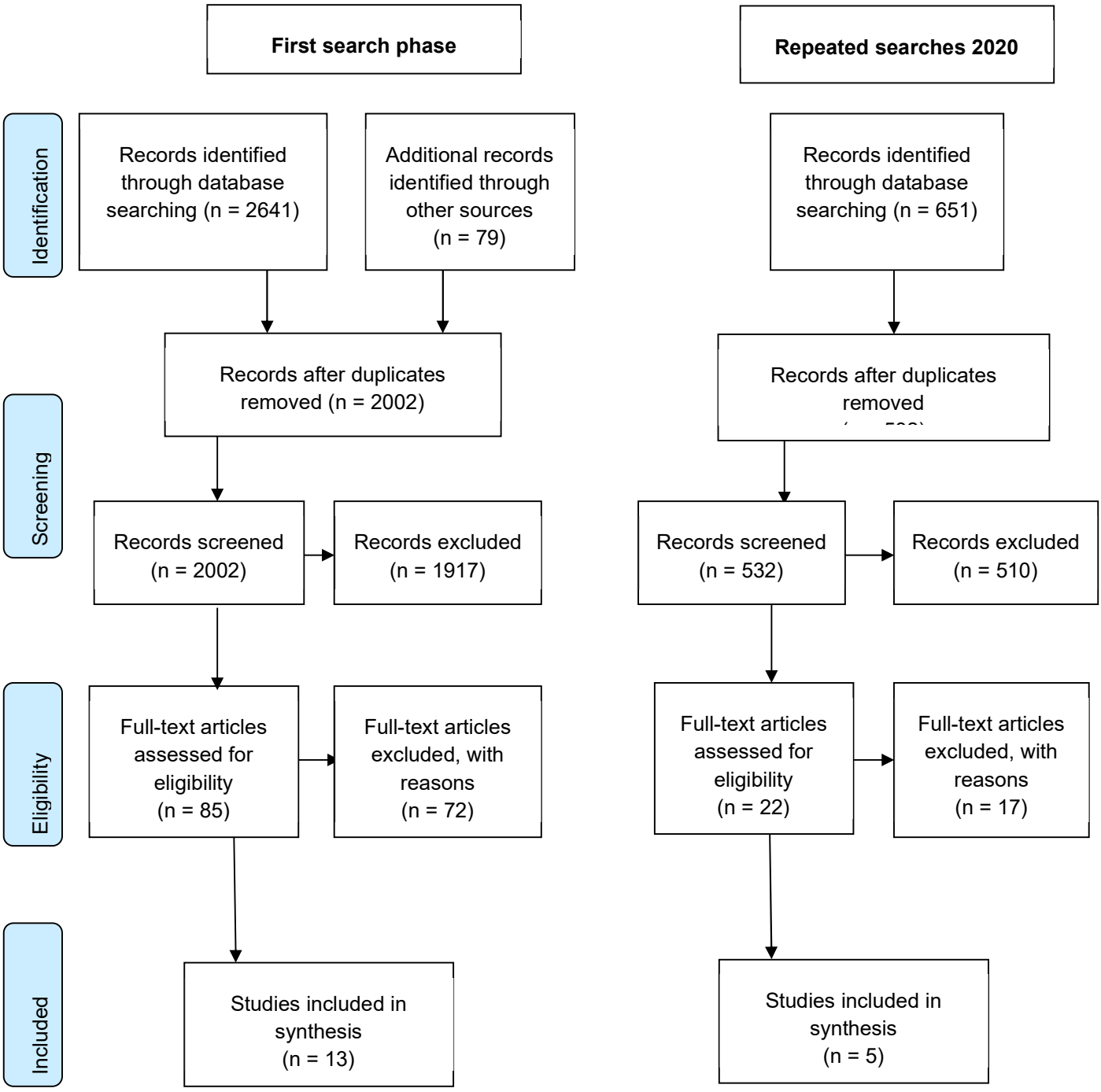


Figure 3 PRISMA Protocol for systematic review

3.2.2.5 Data extraction

The data extraction framework was structured around PICOS (population, intervention, comparators, outcomes and study designs) in line with the three research questions, and ensuring that the key concepts from the concept map were included (see Appendix A). The critical appraisal (adapted from Rees et al. (2009)) was conducted concurrently with the data extraction, and studies were categorised as low, medium and high quality. The data was analysed through thematic analysis, and a narrative synthesis of the 18 papers was built in line with the three research questions. The research questions were used as the basis for the data extraction framework and deductive themes for data analysis. The narrative synthesis was developed in line with Popey et al.'s (2006) guidance on the process of enabling rigour through narrative synthesis. Subsequently, inductive themes were built up through repeated readings and engagement with the data to explore cross-cutting themes across the included studies, in order to tell the story of the research body.

3.2.2.6 Critical appraisal framework

The critical appraisal framework (see Appendix A) was primarily adapted from Rees et al. (2009), with additions from Snape et al. (2017) and the EPPI-Centre (2003). Similar to the data extraction framework, this was created through an iterative process and piloted with key papers before the 18 included records were evaluated. A traffic light and scoring system was applied, in order to identify rigour and quality of studies. The studies were rated according to the pre-defined quality criteria, and were scored 0-2 points per category, along with a narrative assessment.

3.3 Phase 2

This phase of the work aimed to explore psychological barriers to pro-environmental behaviour change in more depth, by focusing on a specific high-impact behaviour: meat consumption.

3.3.1 Research questions

This work was structured around the overarching research question: 'What role do psychological barriers have in the pro-environmental behaviour change mechanism?'

- RQ4: How can psychological barriers to pro-environmental behaviour change affect meat consumption in individuals?
- RQ5: How does Psychological Distance manifest as a barrier to meat consumption reduction?
- RQ6: How can these psychological barriers be overcome?

3.3.1.1 Rapid evidence reviews: critical reflections

Rapid evidence reviews (RERs) are systematically structured evidence or literature syntheses, which are usually responding to a specific need or call for evidence. It is a popular tool for by policy makers as it balances comprehensiveness with efficiency and this broad topic on meat consumption behaviour change was proposed by DEFRA. There was an evidence need around the effectiveness of interventions related to reducing meat consumption, which is in keeping with common uses for rapid evidence reviews which tend to explore effectiveness of interventions (namely policies). Rapid evidence syntheses balance speed with comprehensiveness, as RERs are most appropriate (as in this case) for research questions related to a specific policy or evidence need. The specificity of the research question enables tighter parameters to be drawn around the inclusion and exclusion criteria in order to collect the most useful data to answer the research question.

Much like the issues around inconsistency and application found across the use of systematic reviews (Section 3.2.1.1), these are also found within rapid evidence reviews despite the rational for conducting a RER usually being

distinct from the rationale for using a full systematic review. The broad principles of replicability, transparency and rigour apply to both, however the rapid evidence review differs in where the boundaries are drawn around the literature in order to balance comprehensiveness and speed, or focus the literature around a highly specific question. The slightly increased flexibility this allows has enabled a broader disciplinary application of RERs, compared to systematic reviews which are still broadly dominated by medical and health research.

3.3.2 Methods

A rapid evidence review requires similar steps to a systematic review, including a protocol designed around a question or need, and then search string development leading to sourcing literature which then needed to be sifted for relevance based on a pre-defined set of inclusion and exclusion criteria. Efficiencies are made by drawing tighter parameters around the PICOS framework (population, intervention, comparisons, outcomes, study), such as narrowing the publication date boundary, focusing on one or a narrow set of interventions, or focusing on a specific population. In this case, it differs from a full systematic review as it; 1) only involves 1 reviewer, 2) limited searches to 3 databases, and 3) the searches were not repeated several months later, as is common with systematic reviews.

3.3.2.1 Scoping search

The research questions were developed through concept mapping and a scoping search of existing literature around meat consumption behaviour. A scoping search identified five key papers (Vermeulen et al., 2012; Stoll-Kleemann and Schmidt, 2017; Bianchi et al., 2018; Sanchez-Sabate et al., 2019; Taufik et al., 2019), which were used to develop a concept map that informed the PICOS framework (population, intervention, comparison, outcome, and study context), and subsequent search strings.

3.3.2.2 Search strategy

The exclusion and inclusion criteria were developed in line with the research questions, using the standard PICOS format (**Table 3**). The search strategy was developed iteratively from the inclusion/exclusion criteria, and trialled across different databases. A review by Taufik *et al*. (2019) helpfully included very detailed search strings, and this ensured the current study was as specific as possible, especially in regards to synonyms of behaviour and exclusions of study participants.

	Inclusion	Exclusion
Population	European, ideally UK based research. n > 10 (if experimental)	Children Non-humans n < 10
Intervention	Psychological barriers to behaviour change	Medical interventions (i.e. health-related research). Environmental structuring
Comparison	Different psychological barriers and subsequent impacts	
Outcomes	Behavioural actions: Measured actual meat consumption or intended meat consumption And: Behavioural determinants: psychological barriers, values, attitudes, habits	
Study design	Empirical study Experimental Quasi-experimental Qualitative	Theoretical Modelling Review
Study design context	Real-world	Lab-based (in order to ensure external validity of measures)
Conceptual	Psychological barriers	Health-related behaviour change

	Reduced meat consumption Increased meat alternatives Move to vegetarianism/veganism/ pescatarianism/flexitarianism/ climate-friendly diet/ sustainable food consumption etc. Climate-friendly/ eco-friendly/ sustainable consumption	
Time	Since 2010	Pre 2010
Type of publication	Academic publications Grey Literature (Gov. reports, NGO reports, third party consultant reports etc.)	Anything else, i.e. media, blogs, theses.
		If full text not available through University of Leeds. Non-English language

Table 3 Inclusion and exclusion criteria for rapid evidence review.

The searches were run and downloaded into Zotero (Appendix B). Web of Science, Scopus and Google Scholar were used. Google Scholar returned 1640 results and the first 200 were included, to balance comprehensiveness with speed. Citation searching of the 5 key papers was then conducted as a check of saturation, and 1 paper was added. This ensures confidence in the comprehensiveness and effectiveness of the search strings. The full searches returned 277 results. The first sift applied the inclusion and exclusion criteria to the title and abstract, with a full paper analysis for the second sift. The two rounds of sifting resulted in 7 papers being included in this study (PRISMA diagram; Appendix B). Although this is a narrow band of research to analyse due to the specificity of the research question, the small group of studies are situated within the broader literature, and space is opened up for theoretical analysis and development.

3.3.2.3 Data extraction

The data extraction framework was based on the research questions (Appendix B), and the use of the critical appraisal framework distinguishes a systematic or rapid evidence review from standard literature reviews. This was adapted from Rees *et al*. (Rees et al., 2009), as it combines the key elements of critical appraisal and risk of bias, whilst being relatively low intensity (Appendix B). The papers were scored 0-3 for each criterion, with a maximum 18 points, and this corresponded to a low (0-6), medium (7-12) or high (13-18) score. This was amended based on findings from Phase 1, as a higher degree of variation in critical appraisal scores was deemed to be useful to more clearly distinguish between the studies.

3.3.2.4 Data synthesis

Once the data was extracted, a narrative, thematic approach drove the synthesis. This followed two tracks: study outcomes and policy recommendations. Study outcome data was themed deductively; in accordance with categories within Kollmuss and Agyeman (K&A) (Kollmuss and Agyeman, 2002), and Spence *et al*.'s (Spence et al., 2012) application of psychological distance. The Kollmuss and Agyeman (2002) model provide detailed barriers such as “existing values prevent learning”, however, for simplicity and to enable

comparison, barriers were grouped into themes of values, emotion, knowledge and habit. Study outcomes cannot be directly compared; however, findings can be synthesised to extract trends and potentially contradictory and complementary results. ‘Study outcomes’ refer to the findings and conclusions for each study that relate to psychological barriers. Policy recommendations were inductively themed, by iteratively identifying common threads and findings. The study outcomes and policy recommendations were differentiated in order to critically assess whether the recommendations for policy align with the barriers identified, and what any discrepancy might reflect.

3.4 Phase 3

This phase of work aimed to bring together findings from Phase 1 and 2, in order to test insights from theoretical and experimental design findings in the systematic review with conceptual and empirical findings in the rapid evidence synthesis on psychological barriers to change.

3.4.1 Research questions

- RQ7: What are the behavioural effects of an environmental VR intervention over time?
- RQ8: What are the effects of an environmental VR intervention on psychological distance?

3.4.2 Experimental design: critical reflections

These research questions, and a large part of the research design, were developed iteratively based on a foundation that the evidence reviews provided. Therefore, it is necessary to outline some of the initial findings from Phase 1 and 2 to ground the decisions for the experimental design. The systematic review found that the majority of the literature which explored the effect of a piece of VR content on behavioural determinants utilised experimental or quasi-experimental designs, therefore an experimental design was chosen for these research questions.

The systematic review identified included a lack of longitudinal or repeated measures, a focus on small-scale behaviours, and a lack of externally validated metrics. Therefore, this research aimed to build on previous work by addressing these limitations. The systematic review found that the area of research exploring the effect of VR content on pro-environmental behaviours was very new and evolving outwards, resulting in expansion of understanding but less emphasis on building on previous work. Therefore, I wanted to ensure that the metrics used for measuring behavioural determinants and outcomes were pre-existing, externally validated metrics, to enable comparison to previous work.

Additionally, utilising a repeated measures design enabled a measure of the effect over time, as the systematic review found a lack of data extending beyond a week post-intervention.

Experimental designs are considered to be the most rigorous approach to testing the effect of an intervention, and Abrahamse et al. (2016) identified three fundamental elements of an experimental design which distinguishes it from quasi-experimental design or other study designs, which are 1) systematic manipulation of variables, 2) random assignment of participants to conditions, and 3) presence of a control group. However, a significant limitation of experimental designs is the external validity of the 'laboratory' tests. External validity can be improved by repeating experiments across different populations and contexts, however that is beyond the parameters of this research. One way to improve the external validity of laboratory experiments is to use externally validated measures and metrics. Therefore, a critical analysis of behavioural metrics was required to choose the most appropriate range of metrics to align with the behavioural determinants of the Kollmuss and Agyeman (2002) model and behavioural outcomes (Section 3.4.2.1).

Conceptually, the rapid evidence review (RER) identified gaps in the understanding of meat consumption behaviours, and specifically, psychological barriers to behaviour change, which this phase of the research aimed to build on. The content used as the VR intervention was chosen primarily due it's clear relationship to issues around meat consumption, in order to build on findings in Phase 2, and satisfy the requirements from Phase 1 around exploring high-impact behaviours.

3.4.2.1 Measuring pro-environmental behaviour – metric analysis

In order to identify the most relevant behavioural metrics for the research questions and the concepts to be measured (based on the Kollmuss and Agyeman (2002) model of pro-environmental behaviour), a review of metrics is conducted. There is an increasing array of pro-environmental behavioural metrics, published with varying degrees of dimensionality, validity and reliability

(Markle, 2013). The increasing choice of metrics prevents the accumulation of knowledge of the effectiveness and application of those scales and the behaviours and contexts they aim to explain. Research designs often 'pick and choose' sections or elements from existing metrics which can affect the integrity and validity of the measure (Abrahamse et al., 2016). Therefore, this research did not develop a new behavioural metric but applied previously validated measures of pro-environmental behaviour change, affective/emotional response, environmental attitudes, environmental values, environmental knowledge and a measure of psychological barriers (psychological distance) as determined by the Kollmuss and Agyeman (2002) model (**Figure 7**).

In order to select the most appropriate measures and metrics for the research questions and components, a review of relevant intervention studies and evaluations of pro-environmental and behavioural metrics was conducted.

3.4.2.2 Pro-environmental behaviour

Markle (2013) conducted a rigorous review of measures of pro-environmental behaviour, which was used to develop a measure of high-impact behaviour change (the 'pro-environmental behaviour scale' (PEBS)). This review provided a theoretically grounded measure of PEB, it was rigorously tested for internal and external validity, and presented the experimental development of the scale clearly. It also came from a position of recognising and questioning the increasing expansion of measures of PEB which prevents 'cumulative science' (as termed by Lange and Dewitte (2019)). However, the priority actions identified as high impact are tenuously ambitious, i.e. "how often do you switch off standby modes of appliances or electronic devices?" (Markle, 2013, p909). This review was followed in 2019 by Lange and Dewitte (2019) with a review of self-report scales of measuring PEB. This review presents a comprehensive literature review of 33 measures of environmental behaviour which have been either used in multiple studies or been psychometrically evaluated in the creation of the measure. I have used this as the basis of my review due to the comprehensiveness of this work.

In order to select relevant metrics for the experimental design, I initially discounted scales which:

- Were not designed for, or had not been tested on adults,
- Measured very specific behaviours/only covered one behavioural domain, or was based on organisational behaviour change,
- Were designed for, or tested on a specific population which had not been validated elsewhere (e.g. tourists, members of environmental organisations),
- Had too few items to be considered a holistic measure of behaviour change.

13 metrics remained and these were analysed based on the following components:

- Behavioural type and domain/s covered (e.g. recurring and high-impact behaviours)
- Number of items (comprehensiveness vs. usability)
- Construction of metrics (inverted questions, question type, external and internal validity)

Lange and Dewitte's (2019) recommendation (due to frequency of application and therefore increased rigour and external validity) is to use Kaiser's (1998) General Ecological Behaviour Scale, however it is a more general measure of pro-social tendencies and has a strong normative framing which could influence the social desirability of the responses. Therefore this resulted in Brick et al.'s (2017) Recurring Pro-Environmental Behaviour Scale being selected. This measure covers several behavioural domains, has inverted scales which enables data quality checks, and includes some high impact measures, therefore is the best fit for this research.

3.4.2.2.1 Environmental values

The New Ecological Paradigm Scale is possibly the most commonly used metric across behaviour change research, therefore this would enable buildable and comparable research. It has been used as a measure of factors such as environmental attitudes, beliefs and values (Dunlap et al., 2000), or other behavioural determinants which are inherently value-laden, for decades since its creation in 1978. This was revised in 2000 by Dunlap et al. to create the 'Revised New Ecological Paradigm Scale' to update the language and broaden the components of an ecological worldview.

3.4.2.2.2 Environmental knowledge

The concept of knowledge of a subject as complex and broad as climate change and environmental issues presents difficulties with measurement, in the context of this intervention study and the risk of biasing results with quite normative statements or questions. Awareness of consequences relates environmental knowledge and awareness to the individuals' behaviour directly, therefore this metric was explored, however the reliability was found to be lower than measures of 'environmental concern' which is often used as a comparator (Snelgar, 2006; Ryan and Spash, 2012). Early development of the 'awareness of consequences' scale includes Maloney et al., (1975) which focused on ecological awareness, and this was taken and integrated into the Value-Belief-Norm theory (Stern et al., 1995). Awareness of consequences has been largely subsumed by 'environmental concern' as a measure. Studies which have explored the relationship between these two factors, do so within the 'values' sphere (e.g. (Hansla et al., 2008; Hoyos et al., 2015; Ryan and Spash, 2012;)), however it could also be argued that these two measures could be explored through the lens of psychological distance. van der Linden's (2015) measure of environmental knowledge was chosen due to the multi-component structure (causes, impacts, responses) which enables a comprehensive analysis of environmental knowledge (which aligns with the VR intervention which shows multiple environmental themes).

3.4.2.3 Emotional/affective response

Affective response is a commonly explored behavioural outcome and determinant across VR research specifically, due to the assumption that an increased emotional response could influence subsequent behavioural intention. Due to the VR intervention having key themes of nature, land use and animal-self interaction, the 'Connectedness to Nature Scale' (CNS) was chosen as it assesses value systems (similar to the New Ecological Paradigm scale). The 'Inclusion of Nature in Self' was also considered however the CNS is a slightly longer and broader version of assessing how the individual values and interacts with the natural world.

Few standardised, externally validated measurement options exist for emotional responses, potentially due to the need to have context specific measures. However, the Self-Assessment Manikin (SAM) (**Figure 4**) was chosen to measure the experiential emotional response (used by Giacomin and Bertola (2012) but first developed by (Bradley and Lang, 1994)) due to the simplicity and visual representation of two key components of emotional response.

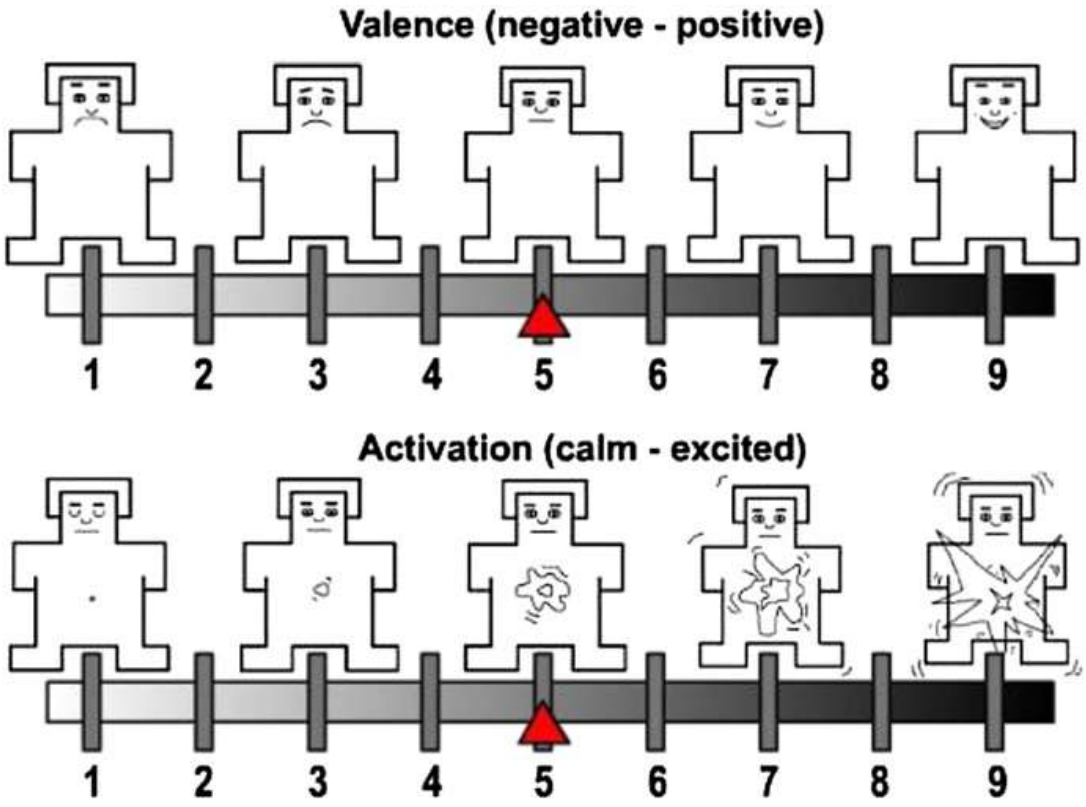


Figure 4 Self-assessment manikin (Bradley and Lang, 1994)

3.4.2.4 Experiential factors

Technological and experiential factors need to be accounted for such as realism and vividness, which may influence how the individual reacts to that content. Presence is defined by Ahn (2011, p.22) “as the subjective unit of evaluating the realism of the mediated experience”. Presence is the dominant variable which is measured across behavioural studies which utilise VR, as identified by the systematic review and wider literature search (Chapter 4). Ahn (2011) identified three dimensions of presence: self (extent to which the virtual self feels like the real self), spatial (how well the virtual environment responds to an individual), and social (how well interactions occur in the virtual space). Therefore, I measured self-presence as the experience was not interactive or involve interactions with others or avatars, therefore spatial and social presence are not applicable. The systematic review (Chapter 4) identified common metrics for self-presence, with Witmer and Singer's (1998) measure of presence used due to its application and validity for studies using passive (non-interactive) VR content.

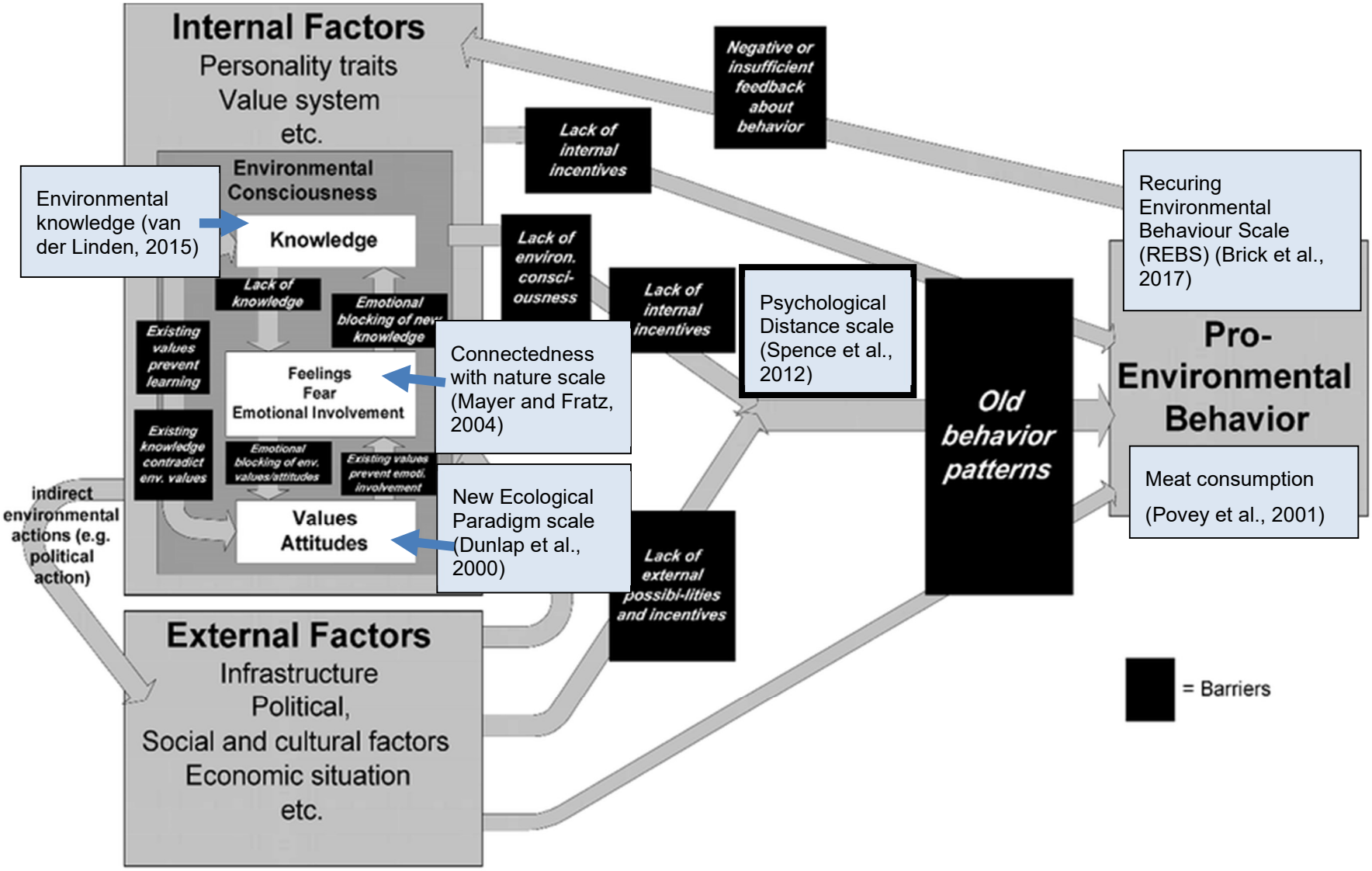


Figure 5 Theoretical framework with metrics for measurement (adapted from Kollmuss and Agyeman (2002))

3.4.3 Content analysis framework

In order to select the virtual reality content for the experiment, an exploration of freely available, medium-length films or clips was conducted.

There were several requirements:

- Clip length (5-8 minutes)
- Conceptually: themes of meat consumption (through issues such as land use, deforestation, ethics of farming practices)
- Suitable for use with a range of VR compatible devices

Commonly used and accessible platforms were searched for factual, documentary-style pieces which fitted the initial eligibility criteria, including YouTube (360 content), with.in, oculus VR store. Technical, accessibility and quality criteria were considered in order for the content to work effectively across different hardware, therefore the content needed to be compatible with the main brands and versions of VR hardware. Only professionally produced content was short-listed, and the final selection made after initial piloting.

3.4.3.1 Experimental design

I applied a between-group experimental design composed of the VR group and the control group, within a pre- and post-test intervention study. Participants were randomly allocated to either the VR condition or the control condition in a virtual study (using their own VR equipment). The once the participants had completed the consent form (and in the case of the VR group; a health screening) all participants completed the pre-test questions, measuring a range of behavioural determinants determined by the metric review, with the VR condition group undertaking a behavioural intervention. The VR participants were asked to watch a short film using their VR headsets; a 10 minute film ('This Is Climate Change: Feast') which follows the process of beef farming in the Amazon and highlights a number of interrelated issues such as deforestation, land use, land degradation, meat consumption, and climate change (Figure 6). The control group had no intervention and participants solely completed the first half of the survey, to provide the baseline data. A post-test

questionnaire was then completed measuring the same behavioural determinants again with experiential questions for the VR condition only. The virtual experiment took between 5-15 minutes for the control condition and 25-55 minutes for the VR condition. The post-test questionnaire was repeated after two-three weeks (for both conditions) to explore any decay rate effect of the intervention. The survey and experimental set up was piloted with a convenience sample in order to ensure logistical efficacy and to check wording and understanding of the surveys. This study was approved by the University of Leeds Ethical Review board (AREA 19-123).

Figure 6: Screenshots from 'This is Climate Change: Feast'.

3.4.3.2 Recruitment

Recruitment was conducted via Prolific, a research recruitment website. Participants were fairly compensated for their time (at a rate of £8/hour), and Prolific enabled us to recruit participants within the pre-defined parameters of being UK-based, and having access to their own VR equipment. There are ethical implications with paying participants to take part, however as the data quality relied on them returning to take part in the follow up study, compensating participants for their time was deemed necessary. They were fairly

compensated for a relatively time-consuming experience (between 20-45 minutes with a shorter follow up 3 weeks later). The platform requires fair compensation for participants, and this enables a high-quality data set to be collected. They could participate in their own time, within a setting of their choosing, however all participants conducted Phase 1 of the experiment within the same 24-hour period. The experiment and survey was hosted on 'Online Surveys'. A randomising URL enabled participants to be randomly assigned to either the control or VR condition survey. There are ethical implications of reimbursing and/or incentivising participants to engage in research projects, which are fully explored in Section 3.5.

3.4.4 Measures

Measures chosen were based on the Kollmuss and Agyeman (2002) model of pro-environmental behaviour, and behavioural components were chosen in line with this model (Table 4). Pre-existing and externally validated metrics were utilised as opposed to creating bespoke measures in order to focus on knowledge building. Full details of the survey design can be found in Appendix C.

Metrics	Pre-test (Time 1)	Post-test (Time 2)	Repeated measure (Time 3)
Revised New Ecological Paradigm scale	X	X	X
Connectedness with nature scale	X	X	X
Environmental knowledge	X	X	X
Psychological Distance	X	X	X
Recurring Pro-environmental Behaviour Scale (REBS)	X		X
Meat consumption	X		X
Socio-demographics	X		
VR group only:			
VR use	X		
Presence		X	
Emotional response		X	
Experiential questions:		X	

How did the film make you feel? *What thoughts did the film provoke?* *What message do you think the film is trying to convey?*			

Table 4 Metrics used within survey design, all questions applied to all participants, unless otherwise specified.

3.4.5 Measured behaviour

3.4.5.1 Recurring Pro-environmental Behaviour Scale (REBS)

The Recurring Pro-environmental Behaviour Scale (REBS) (Cronbach's α=0.78) is adapted from (Brick et al., 2017)), with the language adapted to suit a UK audience. REBS is used as the outcome measure (i.e. behaviour) within the Kollmuss and Agyeman (2002) model. It is constructed of 21 questions, measured across 5-point Likert scales (from 1 (never) to 5 (always)), with five reverse coded questions. A participant's score is the mean across all questions. In this study, the flying component was removed by recommendation of the metric's author due to Covid-19 affecting the reliability of the flying parameter (Brick, 2022)).

3.4.5.2 Meat consumption

Meat consumption is measured due to it being a high-impact and under-researched behaviour. A key theme within the VR film meat consumption and production therefore meat consumption was chosen as an indicator behaviour to explore. In addition to measuring self-reported weekly meat consumption, I applied measures adapted from Povey et al. (2001). This involved measuring general perception, health benefits, pleasantness and enjoyment of vegan, vegetarian and meat-eating diets on 1-7 Likert scales (from -3 (strongly agree) to +3 (strongly disagree)). This measure of attitude is calculated by the mean score for each diet.

3.4.6 Behavioural determinants

3.4.6.1 Revised New Ecological Paradigm (NEP) scale

The Revised NEP was created by Dunlap et al. (2000), and for this thesis it is used to measure values and attitudes (in the Kollmuss and Agyeman (2002) (K&A) model of pro-environmental behaviour). There are 15 items, measured on a 5-point Likert scale. “Agreement with the eight odd-numbered items and disagreement with the seven even-numbered items indicate pro-NEP responses” (Dunlap et al., 2000, p433)), therefore the odd numbered items are standardised (i.e. reversed) to enable a total score to be calculated for each participant.

3.4.6.2 Connectedness with nature scale

The ‘connectedness with nature’ scale (Mayer and Frantz, 2004) is used as a measure of ‘feelings, fear, emotional involvement’ (Kollmuss and Agyeman, 2002) to measure the emotional and affective elements of the intervention. This was chosen due to the dominant theme of nature within the VR intervention. It is measured on a 5-point Likert scale (from 1(not at all) to 5 (very strongly)), with 3 reverse coded questions, and is calculated through a mean score for each participant.

3.4.6.3 Environmental knowledge

This measure of environmental knowledge is taken from van der Linden (2015) and Leiserowitz, Smith and Marlon (2010), and it measures a range of components of environmental knowledge within three categories; ‘knowledge about climate change’, ‘impact-knowledge items’, and ‘response- knowledge items’, all across a scale of 1-4. Responses were classified as either correct (1) or incorrect (0), and participant scores were calculated by the sum of the correct answers.

3.4.7 Psychological barriers

3.4.7.1 Psychological Distance

This measure of psychological distance was developed by Spence et al. (2012), and in this thesis is it used as the primary 'blocking barrier' (Graves and Roelich, 2021) within the Kollmuss and Agyeman (2002) model, in order to test the assumption that VR brings distant experiences closer to the individual. Psychological distance is not used as a proxy for other barriers within the Kollmuss and Agyeman (2002) model but measured as a new barrier to pro-environmental behaviour change (hence is situated in a separate box to the existing barriers within Kollmuss and Agyeman (2002) model). This metric measures across the four components of psychological distance (geographic (two questions), social (two questions), temporal distance (one question) and uncertainty (five questions)). It is primarily measured through 5-point Likert scales (strongly agree-strongly disagree) with two questions applying variations on this. A participant's score is the sum across all measures, and the internal consistency was found to be high (Cronbach's alpha $\alpha=0.80$).

3.4.7.2 Qualitative data

To collect more nuanced and in-depth data on the VR experience and perception of the experience, three questions are asked: 1) 'How did the film make you feel?', 2) 'What thoughts did the film provoke?', and 3) 'What message do you think the film is trying to convey?'. These questions are asked immediately post-experience in order to collect initial emotional responses.

3.4.8 Experiential data

Experiential variables were found in Chapter 4 to be measured across the research body, in order to check for depth of experience (e.g. through immersion or presence) or as a confounding variable in intervention studies. Therefore, in this experiment, presence was used as an experiential check (along with technical experience questions) to ensure that participants all had a minimum standard of experience. The emotional response experiential data

(Self-Assessment Manikin (Bradley and Lang, 1994)) was used to compare to the qualitative responses.

3.4.8.1 Presence

Presence is measured commonly across VR research as a confounding variable, therefore this research applies a measure from Soliman et al. (2017) (adapted from Witmer and Singer (1998) which measured 14 questions on a 1-7 Likert scale). Three items were reverse coded, therefore once these were corrected, a participant's score was calculated as the mean across all measures.

3.4.8.2 Emotional response

To measure emotional response, the Self-Assessment Manikin (Bradley and Lang, 1994) metric was applied. This involves participants identifying which manikin best reflects their emotional response to the film through two components; valence (negative-positive) and activation (calm-excited). These manikins correspond to 1-9 Likert scales, and the two components are treated separately within a participant's score.

3.4.8.3 Socio-demographics

Only the minimum amount of socio-demographic data should be collected for any given study in order to minimise the invasiveness to participants while providing the necessary covariate data. I deemed it necessary (based on similar studies) to collect gender identity, age bracket, highest general qualification, and location (city, country) (adapted from Whitmarsh (2008).

3.4.9 Data analysis

Initially, I cleaned and standardised the data in order to calculate the scores and metrics (data was removed listwise if responses were incomplete). I analysed all the behavioural determinants, psychological distance components, and experiential factors through ANOVAs, MANOVAs, Friedman tests, Wilcoxon

signed rank test and Mann-Whitney U-tests where appropriate to explore the effect of the VR intervention in comparison to the control group. Additionally, I calculated the Cronbach's alpha measure of internal consistency across all metrics.

For the qualitative data analysis (three free text questions the VR group participants completed post-test), a combination approach of inductive and deductive thematic analysis was applied. Inductive themes were derived from the three questions separately in turn. Deductive themes were then applied in the context of psychological distance (identifying explicit or inferred reference or application of psychological proximity or distance to the issues or concepts in the film), and components within the Kollmuss and Agyeman (2002) model (knowledge, values, emotions). The data was also analysed to look for explicit or inferred reference to other psychological barriers. This enabled an assessment of a participant’s initial thoughts and feelings post intervention, and provide context for the quantitative findings.

3.5 Ethics

The ethical considerations of this research project were primarily centred on the use of virtual reality. The bulk of the ethical concerns were based in Phase 3 due to Phase 1 and 2 not involving human participants. The insights, especially from the systematic review on the use of VR in this space, heavily informed the ethical considerations for Phase 3.

Ethical considerations were front and centre in this research, as concepts and discussions around climate change can evoke strong emotional and behavioural responses, and often are utilised to catalyse a pro-environmental behavioural response. VR content was chosen which was deliberately provocative but in line with many other documentary-style 360° videos available and commonly used by NGOs/communications organisations involved in climate change or environmental campaigning. However, due considered was given to the risk of emotional distress, such as feelings of helplessness, apathy or overwhelm so often associated with climate change communications,

especially considering the virtual nature of the interaction with participants, which reduces the ability to discuss the issues raised in the experiments with participants. Participants did have the option to message or email concerns to the lead researcher. This research was approved by the University of Leeds ethics board (AREA 19-123).

3.6 Positionality

Positionality and my own influence on the research process and findings is something I have been increasingly aware of throughout the research journey (2018-2023).

I am a social scientist with a background in sustainability, therefore I bring a certain worldview to this research which must be acknowledged. There are normative assumptions which I have attempted to be mindful of throughout, primarily around the argument that individuals ‘should’ make behavioural changes in order to mitigate climate change and their impact on the environment. The responsibility of individuals to contribute to climate change mitigation efforts is acknowledged as a normative assumption within this work. My position on the tensions between individual and system level change firmly sits between these approaches, and a clear belief that both dimensions are required for meaningful and just change. System change is necessary, and individuals can contribute to pushing for this, and a motivated, educated, caring, pro-environment society are necessary in order to push for systemic change. All the assertions and suggestions I make are with caveats around agency, historic and differentiated responsibility and the structural support which is required to ensure a just transition. My driving force behind this work is a desire to improve behavioural interventions, possibly through virtual reality, which can then encourage or catalyse pro-environmental behaviour change. Throughout this work, I focus on climate change mitigation behaviours, and the mitigation context more broadly. Climate change adaptation and resilience are vital and integrating mitigation and adaptation decisions at a policy level can ensure that conflicts are avoided and co-benefits potentially created (Grafakos et al., 2020).

The context of the research was chosen to focus on the UK, partly for logistical ease, but partly because of the historical responsibility for heavy industrialisation and associated carbon emissions that the UK holds, but also due to the consistently high per capita emissions that UK residents are responsible for.

Throughout this research process, I have documented the research process in a research diary which I examine in Chapter 8. This was a crucial tool for me to reflect on my own process as well as capturing the key decisions within a research journey.

3.7 Covid-19

Prior to the emergence of Covid-19, the plan for Phase 2 and 3 of the research was to conduct in-person experiments (around Leeds at participants' place of work, with key participating organisations such as ITV), followed by in-person follow-up interviews with interested participants. The experiments were due to be carried out in April 2020, therefore when the UK went into lockdown in March 2020 the research plans were entirely disrupted. In the months that followed, everyone was living with huge uncertainty, which also applied in this setting as I was unable to know when or if the experiments would be able to run as planned.

As well as the logistical hurdles this presented, this also resulted in a relatively significant change in research questions. I was fortunate to have the rapid evidence review work on psychological barriers to meat consumption underway (as a side-project initially) which was able to be explored more fully and integrated into the PhD body of work. This has led to two results chapters consisting of a systematic review and a rapid evidence review, due to the need to conduct desk-based research for the majority of the research process.

A decision was made for the experimental work to be adapted to fit online and virtual delivery, and data collection was conducted in November 2021. However, due to time restrictions, this meant the interview phase was precluded and data collection focussed on collecting a good quality sample for the experimental design.

3.8 References

Abrahamse, W., Schultz, P.W. and Steg, L. 2016. Research Design for Environmental Issues In: R. Gifford, ed. Research Design for Environmental Psychology. UK: John Wiley & Sons, Ltd, pp.53–70.

Ahn, S.J. 2011. Embodied Experiences In Immersive Virtual Environments: Effects On Pro-Environmental Attitude And Behavior.

Bianchi, F., Dorsel, C., Garnett, E., Aveyard, P. and Jebb, S.A. 2018. Interventions targeting conscious determinants of human behaviour to reduce the demand for meat: a systematic review with qualitative comparative analysis. International Journal of Behavioral Nutrition and Physical Activity. 15.

Boland, A., Cherry, G. and Dickson, R. 2017. Doing a systematic review: A student's guide 2nd ed. Sage.

Bradley, M.M. and Lang, P.J. 1994. Measuring emotion: The self-assessment manikin and the semantic differential. Journal of Behavior Therapy and Experimental Psychiatry. 25(1), pp.49–59.

Brick, C. 2022. 'Recurring Pro-Environmental Behaviour Scale', Email correspondence to author, 31/01/22.

Brick, C., Sherman, D.K. and Kim, H.S. 2017. "Green to be seen" and "brown to keep down": Visibility moderates the effect of identity on pro-environmental behavior. Journal of Environmental Psychology. 51, pp.226–238.

Creswell, J., W. and Creswell, J.D. 2018. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* Fifth. Los Angeles: SAGE Publications.

Dunlap, R.E., Liere, K.D.V., Mertig, A.G. and Jones, R.E. 2000. New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. Journal of Social Issues. 56(3), pp.425–442.

EPPI-Centre 2003. Review Guidelines for Extracting Data and Quality Assessing Primary Studies in Educational Research. Version 0.9.7.

Giacomin, J. and Bertola, D. 2012. Human emotional response to energy visualisations. International journal of industrial ergonomics. 42(6), pp.542–552.

Gough, D. and Elbourne, D. 2002. Systematic Research Synthesis to Inform Policy, Practice and Democratic Debate. Social Policy and Society. 1(03).

Greenhalgh, T., Wong, G., Westhorp, G. and Pawson, R. 2011. Protocol - realist and meta-narrative evidence synthesis: Evolving Standards (RAMESES). BMC Medical Research Methodology. 11(1).

Grafakos, S., Viero, G., Reckien, D., Trigg, K., Viguie, V., Sudmant, A., Graves, C., Foley, A., Heidrich, O., Mirailles, J.M., Carter, J., Chang, L.H., Nador, C., Liseri, M., Chelleri, L., Orru, H., Orru, K., Aelenei, R., Bilska, A., Pfeiffer, B., Lepetit, Q., Church, J.M., Landauer, M., Gouldson, A. and Dawson, R. 2020. Integration of mitigation and adaptation in urban climate change action plans in Europe: A systematic assessment. Renewable and Sustainable Energy Reviews. 121, p.109623.

Graves, C. and Roelich, K. 2021. Psychological Barriers to Pro-Environmental Behaviour Change: A Review of Meat Consumption Behaviours. Sustainability. 13(21), p.11582.

Haddaway, N.R. and Bilotta, G.S. 2016. Systematic reviews: Separating fact from fiction. Environment International. 92–93, pp.578–584.

Haddaway, N.R., Woodcock, P., Macura, B. and Collins, A. 2015. Making literature reviews more reliable through application of lessons from systematic reviews: Making Literature Reviews More Reliable. Conservation Biology. 29(6), pp.1596–1605.

Hansla, A., Gamble, A., Juliusson, A. and Gärling, T. 2008. The relationships between awareness of consequences, environmental concern, and value orientations. Journal of Environmental Psychology. 28(1), pp.1–9.

Hoyos, D., Mariel, P. and Hess, S. 2015. Incorporating environmental attitudes in discrete choice models: An exploration of the utility of the awareness of consequences scale. Science of The Total Environment. 505, pp.1100–1111.

Kaiser, F.G. 1998. A General Measure of Ecological Behavior. Journal of Applied Social Psychology. 28(5), pp.395–422.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research. 8(3), pp.239–260.

Lange, F. and Dewitte, S. 2019. Measuring pro-environmental behavior: Review and recommendations. Journal of Environmental Psychology. 63, pp.92–100.

Lange, F., Nielsen, K.S., Cologna, V., Brick, C. and Stern, P.C. 2021. Making theory useful for understanding high-impact behavior. A response to van Valkengoed et al. (2021). Journal of Environmental Psychology. 75, p.101611.

van der Linden, S. 2015. The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. Journal of Environmental Psychology. 41, pp.112–124.

Maloney, M.P., Ward, M.P. and Braucht, G.N. 1975. A revised scale for the measurement of ecological attitudes and knowledge. American Psychologist. 30(7), pp.787–790.

Markle, G.L. 2013. Pro-Environmental Behavior: Does It Matter How It's Measured? Development and Validation of the Pro-Environmental Behavior Scale (PEBS). Human Ecology. 41(6), pp.905–914.

Mayer, F.S. and Frantz, C.M. 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology. 24(4), pp.503–515.

Nielsen, K.S., Cologna, V., Lange, F., Brick, C. and Stern, P.C. 2021. The case for impact-focused environmental psychology. Journal of Environmental Psychology. 74.

O'Leary, D.F., Casey, M., O'Connor, L., Stokes, D., Fealy, G.M., O'Brien, D., Smith, R., McNamara, M.S. and Egan, C. 2017. Using rapid reviews: an example from a study conducted to inform policy-making. Journal of Advanced Nursing. 73(3), pp.742–752.

O'Leary, B.C., Kvist, K., Bayliss, H.R., Derroire, G., Healey, J.R., Hughes, K., Kleinschroth, F., Sciberras, M., Woodcock, P. and Pullin, A.S. 2016. The reliability of evidence review methodology in environmental science and conservation. Environmental Science & Policy. 64, pp.75–82.

Petticrew, M. and Roberts, H. 2006. Systematic reviews in the social sciences. Blackwell Publishing.

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K. and Duffy, S. 2006. Guidance on the conduct of narrative synthesis in systematic reviews: A product from the ESRC Methods Programme [Online]. Lancaster University. [Accessed 31 July 2024]. Available from: http://rgdoi.net/10.13140/2.1.1018.4643.

Povey, R., Wellens, B. and Conner, M. 2001. Attitudes towards following meat, vegetarian and vegan diets: an examination of the role of ambivalence. Appetite. 37(1), pp.15–26.

Rees, R., Oliver, K., Woodman, J. and Thomas, J. 2009. Children's views about obesity, body size, shape and weight: a systematic review. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Ryan, A.M. and Spash, C.L. 2012. The Awareness of Consequences Scale: An Exploration, Empirical Analysis, and Reinterpretation: Awareness of Consequences Scale. Journal of Applied Social Psychology. 42(10), pp.2505–2540.

Sanchez-Sabate, R., Badilla-Briones, Y. and Sabate, J. 2019. Understanding Attitudes towards Reducing Meat Consumption for Environmental Reasons. A Qualitative Synthesis Review. SUSTAINABILITY. 11(22).

Snape, D., Meads, C., Bagnall, A.-M., Tregaskis, O., Mansfield, L. and MacLennan, S. 2017. A guide to our evidence review methods. What Works Wellbeing.

Snelgar, R.S. 2006. Egoistic, altruistic, and biospheric environmental concerns: Measurement and structure. Journal of Environmental Psychology. 26(2), pp.87–99.

Soliman, M., Peetz, J. and Davydenko, M. 2017. The impact of immersive technology on nature relatedness and pro-environmental behavior. Special Issue: New Evidentiary Standards for the Science of Technology and Human Behavior. 29(1), pp.8–17.

Sorrell, S. 2007. Improving the evidence base for energy policy: The role of systematic reviews. Energy Policy. 35(3), pp.1858–1871.

Spence, A., Poortinga, W. and Pidgeon, N. 2012. The Psychological Distance of Climate Change. Risk Analysis. 32(6), pp.957–972.

Stern, P.C., Kalof, L., Dietz, T. and Guagnano, G.A. 1995. Values, Beliefs, and Proenvironmental Action: Attitude Formation Toward Emergent Attitude Objects1. Journal of Applied Social Psychology. 25(18), pp.1611–1636.

Stoll-Kleemann, S. and Schmidt, U.J. 2017. Reducing meat consumption in developed and transition countries to counter climate change and biodiversity loss: a review of influence factors. Regional Environmental Change. 17(5), pp.1261–1277.

Taufik, D., Verain, M.C.D., Bouwman, E.P. and Reinders, M.J. 2019. Determinants of real-life behavioural interventions to stimulate more plant-based and less animal-based diets: A systematic review. Trends in Food Science & Technology. 93, pp.281–303.

van Valkengoed, A.M., Steg, L., Perlaviciute, G., Schultz, P.W., Brosch, T., Gatersleben, B., Nordlund, A., Pahl, S. and Whitmarsh, L. 2021. Theory enhances impact. Reply to: 'The case for impact-focused environmental psychology'. Journal of Environmental Psychology. 75, p.101597.

Vermeulen, S.J., Campbell, B.M. and Ingram, J.S.I. 2012. Climate Change and Food Systems. Annual Review of Environment and Resources. 37(1), pp.195–222.

Whitmarsh, L. 2008. Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response. Journal of Risk Research. 11(3), pp.351–374.

Witmer, B.G. and Singer, M.J. 1998. Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environments. 7(3), pp.225–240.

Woodcock, P., Pullin, A.S. and Kaiser, M.J. 2014. Evaluating and improving the reliability of evidence syntheses in conservation and environmental science: A methodology. Biological Conservation. 176, pp.54–62.

Chapter 4 Virtual reality and pro-environmental behaviour change: a systematic review

Abstract

In order to mitigate for and adapt to climate change and ecological decline, behavioural change needs to occur at all scales. Effective communication is crucial to catalysing pro-environmental behaviour change, and virtual reality (VR) provides new opportunities to bring people closer to distant experiences. The purpose of this study is to identify research gaps and best practice in pro-environmental behaviour research which utilises virtual reality. I conducted a systematic review using three databases, and 18 studies were included in the analysis. I found that the research largely focused on the effect of experiential factors (e.g. immersion, presence) and measured a narrow range of behavioural factors (e.g. environmental attitudes, knowledge). Going forward, research could consider a broader range of behavioural determinants and outcomes, with due consideration given to psychological barriers to behaviour change. There is potential for this interdisciplinary area to be grounded more deeply in theory, to enable greater relevance to a wider pool of researchers and practitioners.

4.1 Introduction

Mitigating for and adapting to climate change and ecological decline requires changes to society at all scales, including the household and individual level. Individual behaviour change and the structures which facilitate this are fundamental to shifting consumption demand (Creutzig et al., 2016), however, technological and economic incentives are prioritised over individual and household level policy (Dubois et al., 2019). A radical approach is required to reduce personal emissions (Capstick et al., 2014) through interventions which target societal and institutional structures as well as individual behaviour change. In this chapter, I focus on the individual as the unit of behaviour change, while recognising how behavioural interventions must exist as part of broader societal shifts. Targeting the individual through behavioural interventions can take many forms such as "*information provision, appeals to values and norms, engagement,*

and restructuring choice options" (Stern, 2020, p.1). Virtual reality is a relatively new avenue of communication for these interventions.

Virtual reality (VR) technology has become increasingly publicly accessible, and is being utilised by marketing agencies, artists and filmmakers who use it as a promotional and communication medium (Rambach et al., 2020). VR is utilised by NGOs (e.g. UN; World Bank), journalists (e.g. New York Times), and filmmakers (e.g. Unfold Stories; Immersive Culture) to raise awareness of environmental issues, primarily through storytelling in 360° video (e.g. 'This is Climate Change', 'Our home, our people') and games ('Tree' and 'The Crystal Reef'). VR experiences can include diorama (stationary image), 1st person experience, interactive virtual environments, 'riding on rails' simulations and 360° media (Linowes, 2015). Technological advances have expanded the potential delivery mechanism for virtual reality, from primarily utilising head-mounted devices, to a variety of social spaces including mobile-based AR games to immersive cinemas (Oh et al., 2018), including haptic feedback, and even scent and temperature (Kort et al., 2003). Popularity as a recreational tool and research tool has increased in line with these technological developments, however research has focused on the potential negative effects of usage, and less on the potential for pro-social and pro-environmental behaviour change through virtual reality (Wang et al., 2021).

There is a rapidly growing body of environment and climate related content, and growing consumer demand for these experiences (Mohamed Elias, et al. 2019; Pan and Hamilton 2018), therefore the impact on behaviour and behavioural mechanisms need to be explored. Virtual reality offers the potential to bring distant experiences, sights, sounds and perspectives closer to the individual, potentially bridging psychological barriers such as psychological distance (Wienrich et al., 2021) in order to engage people about climate change and environmental issues (Raja and Carrico, 2021). Immersive experiences could generate individual relevance for potentially abstract concepts such as climate change (Nicholson-Cole, 2005) by creating a sense of presence which can lead to internalising the experiences (Blascovich and Bailenson, 2011), and increase meaning to the individual.

Advocacy and fundraising campaigners use VR in order to tell stories and change minds, however little evidence exists on the impact of environment-themed VR on pro-environmental behaviour change. Environmental VR research has explored the effect of VR on empathy (Queiroz et al., 2018; Fauville et al., 2020), knowledge (Petersen et al., 2020) and attitudes (Hartmann and Apaolaza-Ibáñez, 2008), therefore I focus on the effect on pro-environmental behaviour.

Pro-environmental behaviour refers to the intentional actions of reducing one's impact on the natural environment (Kollmuss and Agyeman, 2002), and the unconscious actions which result in environmental gain or avoidance of environmental harm (Steg and Vlek, 2009). Campaigning and commercial environmental VR focusses on generating awareness and empathy (Pimentel et al., 2019), and assumes that awareness and empathy lead to behavioural change, however these assumptions need to be examined. Therefore, I explore how virtual reality has been used to research pro-environmental behaviour change, through a systematic review of the literature, in order to summarise existing work and drawing out recommendations for the use of VR. This is the first systematic review which focuses specifically on research exploring pro-environmental behavioural factors and outcomes, building on recent, broader work from Fauville et al. (2020 and Queiroz et al. (2018).

4.1.1 Research questions

The research aims to explore 'how has virtual reality been used to research pro-environmental behaviour?', by exploring the following sub-questions:

RQ1: How is behavioural theory applied across pro-environmental behavioural change research which utilises virtual reality?
RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?
RQ3: How has virtual reality been found to affect pro-environmental behaviour?

This chapter first outlines the methods of the systematic review (section 4.2), followed by a descriptive overview of the literature examined by research question (section 4.3), and a discussion structured around recommendations for researchers and practitioners using VR within pro-environmental behavioural research (section 4.4). This chapter aims to be useful to practitioners working in environmental communications and policy, researchers using VR in behavioural research, and others who are interested in understanding the state of the literature around environmental issues and how VR can be used to influence individual behaviour for environmental good.

4.2 Methods

A systematic review methodology was chosen due to the need to sift large amounts of data from a broad range of disciplines (across psychology, environmental social science, computing, engineering etc.). Due to the novel nature of the research area around pro-environmental behaviour change which utilises VR, the literature thus far is largely explorative and disparate which precludes a meta-analysis.

In this case, a systematic review is defined as a review method which applies a pre-defined protocol, requires more than one reviewer and reviewer corroboration, a PRISMA protocol, amendments to the methodology required to be recorded and justified, and crucially, a critical appraisal of the literature. A systematic review protocol was developed to address the three research questions outlined in Section 4.1.1, under the overarching question ‘How has VR been used to research pro-environmental behaviour?’.

The systematic review framework and methodology (Chapter 3.2) was developed based on critical reflections drawn from both methodological and applied literature, and constitutes a key contribution of this research. The level of iteration (through scoping and piloting) in the early phases of the review process enables confidence in the subsequent searching strategy and final inclusion, within the context of research questions which explore interdisciplinary work which are often hard to encapsulate within the traditional parameters of systematic reviews.

These core principles of systematic reviews and the subsequent methodology provide a framework for future reviews within the environmental social sciences.

The literature searching and sifting process, as well as data collection and analysis was outlined fully in Chapter 3.

4.3 Results

4.3.1 Overview of studies

4.3.1.1 Preliminary synthesis

The searches returned 18 results, from 3371 initial results returned (see PRISMA Protocol; Appendix A), published between 2010-2020. Lead author affiliations were dominated by engineering (n=6), communications (n=5), psychology (n=3), with two lead authors affiliated to an environment/climate department. This is a crude measure of disciplinary spread, but can indicate some elements of the positionality of the researchers involved in the included studies. The geographic scope of the studies is weighted towards Europe (n=8) and North America (n=6) and are situated within those contexts, aside from Nelson et al. (2020), who conducted research in Indonesia, while being based in Germany. Three studies were conducted in Asia and one in Australia. The data is summarised in **Table 5**.

4.3.1.2 Critical appraisal

The critical appraisal found that the body of work is largely *high* quality (n=14), with four studies being classed as *medium* (n=2) and *low* (n=2). The two 'low quality' studies were both conference papers, which prevented sufficient information available to categorise them as higher quality. This indicates a generally high standard of scientific rigour, especially across the methodological areas of data collection, justification of methods and data analysis.

The poorest scoring area was in the 'risk of bias' assessment due to a lack of positionality and reflection of the role of the researcher, where none but Bailey et al. (2015) acknowledged their position in the research. Another common issue was around the clarity of the information presented to the research participants,

and the associated ethical issues. Limitations which were commonly acknowledged by authors were dominated by sampling strategies which had a heavy reliance on self-selecting student participation. Often the limitations associated with this are outlined and examined, such as that age and educational group potentially affecting environmental awareness, and familiarity with VR technology.

The critical appraisal framework is adapted from (Rees et al., 2009) due to the excellent rigour (and associated guidance) it provides. However, as it was created for use in the health sciences, it may be less suitable for such a wide range of disciplines covered; however, it does indicate that the evidence base is generally rigorous.

Citation	Independent variable(s) / component of VR explored	Dependent variable(s)	Outcome (significant effects)	CA*[1]
Ahn, 2011	Immersion, agency, locus of control, perspective taking propensity	Self-efficacy, measured behaviour, behavioural intention, presence, recall	High immersion - higher presence; higher perspective taking propensity - higher behavioural intentions	High
Ahn, Bailenson, and Park 2014	Embodiment	Behavioural intention, measured behaviour, locus of control, awareness of consequences	Higher embodiment - lower napkin use; enhanced locus of control 1 week later (VR condition)	High
Ahn et al. 2016	Embodiment	Body transfer, spatial presence, inclusion of nature in self, connectedness with nature, temporal distance	Body transfer mediated VR experience and INS relationship; embodiment weakened after 1 week	High
Bailey et al., 2015	Vividness and/or personalised messaging	Hot water use (temperature and volume)	Vividness affected water temperature use	High
Ballantyne et al., 2016	Use of IVE[*2] visualisation of climate change	Perception, understanding, agency	IVE increased understanding; preconceptions affected interpretation	Medium
Breves, 2020	Immersion	Spatial presence, environmental connectedness	Higher immersion - higher spatial presence; higher immersion - higher environmental connectedness	High
Calogiuri et al., 2018	Exercise + VR	Environmental restorativeness, presence, affect	Enjoyment increased environmental restorativeness	High

Calvi et al., 2017	Presence, immersion, demographics	Environmental awareness, experience of VR	Demographics (age) affected presence	High
Cepok et al., 2019	Immersion, navigation	Affect, behavioural intention	Immersion + navigation effect emotion (positive),	Medium
Chirico et al., 2020	Communication - statistical info (numerical, concrete, mixed)	Awareness, attitudes, self-reported consumption	Higher presence (concrete and mixed); emotion affected differentially	High
Fan et al., 2010	Educational application for climate change VR	Attitudes to pedagogical experience	Positive experience, promoted discussion	Low
Hsu et al., 2018	Feedback type (exaggerated (EF)/direct (DF)), vividness, personalised messaging	Cognition, attitudes, behavioural intention, emotion	Ambient EF more effective than DF at affecting emotions and awareness	High
Markowitz et al., 2018	Immersion	Knowledge, attitudes, new ecological paradigm, presence	Increased immersion - knowledge gain, maintained over time	High
	Embodiment	Presence, connectedness with nature, new ecological paradigm, movement, knowledge	Both conditions - higher knowledge & attitude, presence associated with knowledge & attitudes	
	Movement	Attitude, inquisitiveness	Higher movement - higher inquisitiveness	
	Water ph. - experience, locomotion technique	Attitude, presence, movement, connectedness with nature (CNS), new ecological paradigm	Presence positively correlated to CNS and attitudes; movement effect on knowledge.	

Nelson et al., 2020	Immersion (unidirectional vs. VR), affect (+v/-v framing)	Donation behaviour, presence, emotion	All conditions affect emotional response; VR affected donation behaviour	High
Nim et al., 2016	Water and carbon footprint estimates	Awareness, attitudes, experience	Effect of lag and latency	Low
Petersen et al., 2020	Narration in pre-training or VR	Behavioural intention, self-efficacy, knowledge, interest	Positive effect on all measures; higher knowledge in pre-training condition	High
Ruscio et al., 2018	Eco-driving training	Driving behaviour, acceptance, workload, driving parameters, cognitive changes	Eco-driving - higher fatigue and cognitive load	High
Soliman et al., 2017	Immersion, content type (natural vs built)	Attitude, connectedness with nature, mood, presence, measured behaviour	Content type affected attitude; immersion and nature content affected connectedness with nature	High

Table 5 Summary table of included studies (*1CA – critical appraisal; *2 IVE – Immersive Virtual Environment; *3 Markowitz is divided into 4 distinct studies represented within Markowitz et al. (2018)).

4.3.2 RQ1: How is behavioural theory applied across pro-environmental behavioural change research which utilises virtual reality?

The studies are drawn from a wide range of disciplines, which have different understandings and applications of theory. Despite the disparity in findings across the research body, what can be concluded, is that behaviour and the behaviour process is understood in different ways, and this could be due to the disciplinary differences across the included studies, or even differences across often highly interdisciplinary teams of researchers.

Explicit theoretical application is inconsistent across the research body. Theory was explicitly referenced through either testing a theory through experimentation or using theory as a framework to examine findings. In terms of behavioural theory, Construal Level Theory (Markowitz et al., 2018) and the Theory of Planned Behaviour (Ruscio et al., 2018) were the only explicit references, with the majority of theoretically grounded studies applying experiential theories including embodied cognition (Ahn, 2011; Ahn et al., 2014), Sheppard's (2005) visualisation framework (Bailey et al., 2015), spatial presence (Breves, 2020), Attention Restoration Theory and Sensory Conflict Theory (both Calogiuri et al., 2018).

However, implicit behavioural theoretical application was also apparent, primarily through Theory of Planned Behaviour (Ajzen, 1991) or the Value-Norm-Belief theory (Stern et al., 1999), through the use of theoretical components for measurement (e.g. a reliance on environmental awareness and attitudes as proxy measures for behaviour). The assumptions within the Theory of Planned Behaviour (or Theory of Reasoned Action) where the "*key determinants of behaviour are attitudes, subjective norms, perceived behavioural control and behavioural intentions*" (Michie et al., 2014, p.433), underline a lot of the research as shown by relying on self-reported behavioural intention or environmental awareness, and the corresponding assumptions that this translates into actual behaviour. The role and importance of psychological distance was referenced, explicitly by Ahn et al. (2014), Ahn et al. (2016), Hsu et al. (2018), Markowitz et al. (2018), but more implicitly by others. Concepts such as cognitive dissonance,

risk, use of the Construal Level Theory which underpins psychological distance, and notions of gaps between intention and action and knowledge and behaviour, relate fundamentally to psychological distance.

4.3.3 RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?

4.3.3.1 Study designs

I found that the research has been overwhelmingly conducted through experimental methods, with 2x2 factorial design, independent samples/between-subject design and repeated measure/within-subject design, constituting the majority of studies. Four studies were quasi-experimental (non-randomised, and non-control) and two applied qualitative methods, including interviews, focus groups and mind mapping. All studies employed an intervention; an immersive experience (plus control, or comparison) in order to explore a behavioural or experiential effect. What is notable is the lack of control groups within the experimental designs, as only 4 studies included a control condition in their experimental designs (Markowitz et al., 2018; Nelson et al., 2020; Ruscio et al., 2018; Soliman et al., 2017).

The majority of studies utilised either pre- and post-test data collection, or post-test only. Only Nim et al. (2016) utilised other methods of data collection, due to the nature of their pilot study which collected feedback on their conceptual approach. Only a minority apply a repeated measures design in order to identify any changes over time or a decay rate; and only two of these were conducted over more than a week. Therefore, there is a research gap in terms of analysing the decay rate of the effects of the VR experience as an intervention.

4.3.3.2 What questions are being asked?

The research questions were found to centre around the effect of experiential and technical factors on pro-environmental behavioural outcomes. For the purposes of this study, 'behavioural outcomes' are conceptualised as dependent variables which encompass a range of behavioural factors (e.g. behavioural determinants and behavioural outcomes). The technological factors explored included the effect of immersion (Ahn, 2011; Breves, 2020; Calvi et al., 2017; Cepok et al., 2019; Markowitz et al., 2018; Nelson et al., 2020; Soliman et al., 2017), haptic feedback (Hsu et al., 2018), level of embodiment (Ahn et al., 2014; Ahn et al., 2016; Markowitz et al., 2018), movement (Calogiuri et al., 2018; Cepok et al., 2019; Markowitz et al., 2018), and use of navigation in VR (Cepok et al., 2019) on behavioural outcomes. Experiential factors included framing and communication manipulations such as varying emotion/affect (Chirico et al., 2020; Nelson et al., 2020), vividness (Bailey et al., 2015; Hsu et al., 2018), narration (Petersen et al., 2020), as well as context-specific content comparisons (low/high water pH diving experience (Markowitz et al., 2018); and the effect of different displays of statistics (Chirico et al., 2020)).

4.3.4 RQ3: How has VR been found to affect pro-environmental behaviour?

The most commonly used independent variables were immersion, messaging and framing, and embodiment. Dependent variables (measured outcomes) included measured behaviour, emotional response, behavioural intention, and environmental attitudes (as shown in **Table 5**). As already identified, technological factors (such as embodiment and presence) were prevalent across both the independent and dependent variables amongst the studies, however this paper focuses on the behavioural dependent variables.

4.3.4.1 Independent variables

4.3.4.1.1 Immersion

Increasing the immersion was the most common independent variable across the studies. Higher immersion was found to increase feelings of, and perception of presence (Ahn 2011; Breves 2020), perspective taking propensity, and increased behavioural intentions (Ahn, 2011). It was also found to affect the relationship between nature and self through increased environmental connectedness (Breves, 2020; Soliman et al., 2017), and leads to increased affect (Cepok et al., 2019; Nelson et al., 2020), as well as knowledge gain (Markowitz et al., 2018). However, Calvi et al. (2017) reported no significant effect of immersion on environmental awareness.

4.3.4.1.2 Messaging and framing

Increasing vividness in the VR messaging was found to affect some measured behaviour (water temperature used (Bailey et al., 2015)). This is corroborated by Hsu et al. (2018) who found vividness combined with personally relevant experiences resulted in increases in cognition, attitudes, and behavioural intention within an exaggerated feedback Virtual Environment (VE). Emotions were affected by messaging/framing (Chirico et al., 2020), however Nelson et al. (2020) found that message framing impacted emotion, but a gap was found between emotion and donation behaviour. Regarding visual framing, experiencing a ‘natural’, as opposed to a ‘built environment’ also affected environmental attitudes (Soliman et al., 2017).

4.3.4.1.3 Embodiment

Embodiment refers to the connection of the body and mind to the experience (Ahn, et al., 2013). Embodiment can be affected by manipulations such as movement, navigation, feedback and exercise due to the relationship between the body and the experience, and how this can affect presence (Pan and Steed, 2019). The only directly measured behaviour was the effect of embodiment on napkin usage, where higher embodiment was found to lower resource use (Ahn et al., 2014). Markowitz et al. (2018) found no significant effect of embodiment, as both low and high embodiment conditions resulted in an increase in knowledge

and environmental attitudes. Calogiuri et al. (2018) also found that movement (exercise which was assumed to positively affect embodiment) resulted in no significant impact on environmental restorativeness, presence or affect. This is supported by Markowitz et al. (2018) who found no significant effect of embodiment on presence or environmental attitudes was found. However, in another study in the Markowitz et al. (2018) paper, higher movement in VR was found to lead to higher interest in environmental issues. This suggests very context specific results, or possibly embodiment affecting certain components of the behavioural process.

4.3.4.2 Dependent variables – behavioural outcomes

While directly measured behaviour was the most common dependent variable; behavioural intention, the nature-self relationship, emotion/affect, and environmental attitudes were also all recorded in five studies each, and will be outlined in turn below. Other measured behavioural outcomes included agency (Ahn, 2011; Ballantyne et al., 2016; Petersen et al., 2020), awareness of consequences (Ahn et al., 2014), perception (Ballantyne et al., 2016), understanding (Ballantyne et al., 2016; Markowitz et al., 2018; Petersen et al., 2020), environmental awareness (Calvi et al., 2017; Chirico et al., 2020; Nim et al., 2016), cognition (Hsu et al., 2018; Ruscio et al., 2018), and environmental interest (Markowitz et al., 2018; Petersen et al., 2020). These categories show the breadth of behavioural determinants and outcomes which were examined across this modest research body.

4.3.4.2.1 Measured behaviour

Measured behaviour was the most commonly measured dependant variable, which included self-reported and directly observed behaviours. Measured behaviour was exclusively focused on small-scale behaviours, i.e. how many napkins a participant used to mop up water (Ahn, 2011; Ahn et al., 2014), water usage (Bailey et al., 2015), tightness of a faucet after water use (Hsu et al., 2018), donation amount (Nelson et al., 2020), and driving behaviour after a training course (Ruscio et al., 2018). These behaviours do cover a variety of behavioural domains, however all measured behaviours were small-scale, context specific behaviours, which highlights potential issues for external validity. Chirico et al.

(2020) and Soliman et al. (2017) apply a broader approach to measured behaviour by measuring self-reported behaviour outside the lab conditions.

4.3.4.2.2 Emotional response (affect)

Emotional responses were measured as outcome variables in five studies (Calogiuri et al., 2018; Cepok et al, 2019; Hsu et al., 2018; Nelson et al., 2020; Soliman et al., 2017) through an array of metrics. Calogiuri et al. (2018) found that an immersive nature experience (both seated and on a treadmill) caused affect to decrease against a baseline compared to a nature walk, however cyber sickness was reported in this study. Emotions such as helplessness and sadness were found to mediate a behavioural response (Cepok et al., 2019), while Nelson et al. (2020) found that cognitive load could create a barrier to emotion translating to behaviour. However, Soliman et al. (2017) found no effect on mood due to either the VR content or experiential variables, although 'fun' and 'pleasantness' were differentially affected by natural and urban VR environments; indicating highly context-specific emotional responses and resultant behavioural responses.

4.3.4.2.3 Behavioural intention

Behavioural intention was only measured in addition to 'measured actual behaviour' in two studies (Ahn, 2011; Ahn et al., 2014), which limits the conclusions which can be drawn around the behavioural intention-action gap. As with measured behaviour, the measures of behavioural intentions were often context-specific to the VR intervention, for instance measuring participants' intention to recycle, purchase or use paper products after experiencing deforestation in VR (Ahn et al., 2014). Movement affected behavioural intention, as 'high propensity' participants (who were able to take the perspective of another) increased their pro-environmental behaviour intention significantly when they could physically control the movements in the experience (Ahn, 2011). Similarly, increasing either immersion or navigation was also found to increase pro-environmental behavioural intentions (Cepok et al., 2019). Immersivity was also explored through exaggerated feedback (EF) and found that "*the use of exaggerated feedback in a virtual environment appears to be an effective strategy for promoting intention to actively engage in pro-environmental activities*" (Hsu et

al., 2018, p.201). Although these are a small number of studies, the results are consistent and a good indication that VR increases behavioural intention, especially where movement and feedback are involved. Petersen et al. (2020) summarises that "*students across conditions showed significant improvements in behavioral change intentions is highly promising, and highlights the potential of IVR*" (Petersen et al., 2020, p.2109).

4.3.4.2.4 Environmental attitudes

'Environmental attitudes' were found to mean different things, for instance, attitudes were measured in relation to awareness of a participant's own behaviour (i.e. awareness of emissions from driving (Ruscio et al., 2018) and awareness of own water usage (Hsu et al., (2018)). Alternatively, 'environmental attitudes' also related to other behavioural determinants such as values through metrics such as the New Ecological Paradigm (Markowitz et al., 2018), where VR interventions were found to result in a significant difference between the pre- and post- test environmental attitudes scores (Markowitz et al., 2018). Similarly, environmental attitudes were also measured through components in the Connectedness to Nature and Inclusion of Nature in Self (INS) measures. Awareness also was found to overlap with 'knowledge', for example through the measurement of the awareness of plastic recycling (Chirico et al., 2020).

4.3.4.2.5 Nature-self relationship

The nature-self relationship was measured most commonly through the 'Connectedness to Nature Scale' (CNS) (developed by Mayer and Frantz, 2004) and the Inclusion of Nature in Self (INS). Higher CNS was found to be significantly correlated to increasing presence (Markowitz et al., 2018) and natural VR environments increased CNS compared to urban environments (Soliman et al., 2017). INS was measured through pictographic representations of animals and the 'self' (Ahn et al., 2016) as well as through attitudes about nature (Soliman et al., 2017). INS was positively correlated with pro-environmental choices (Soliman et al., 2017) and also increased with sensory rich VR experiences (Ahn et al., 2016). The nature-self relationship was also measured through environmental restorativeness, which was found to be associated with enjoyment (Calogiuri et al., 2018). Finally, 'commitment to nature' was found to be mediated by the

degree of body transfer felt by the individual in the virtual environment (Breves, 2020). The dominance of nature-based VR experiences indicates underlying assumptions about the nature-self relationship, in terms of utilising nature and 'wilderness' in order to elicit a behavioural response, therefore there is a need for accurate and valid metrics of the nature-self relationship.

4.4 Discussion

This discussion centres on the implications of the key findings, for both researchers using VR as a tool to explore pro-environmental behaviour, and practitioners using VR as a communication tool. Firstly, the implications of the current theoretical underpinning across the research body are discussed. Secondly, as the underpinning theory determines the conceptualisation of pro-environmental behaviours; how and what behavioural components are measured are discussed. Thirdly, challenges associated with current research designs are outlined, with recommendations and opportunities for future research suggested.

Theory is implicitly applied across the included studies through the research questions posed and the variables measured or manipulated, which centre on the common paradigms present in pro-environmental behavioural research such as the Value-Belief-Norm theory and the Theory of Planned Behaviour. This is shown by the reliance on the same few behavioural dependent variables (i.e. behavioural intention, attitudes, knowledge) being utilised across studies. Broadening the spectrum of theories underpinning pro-environmental behavioural research which utilises VR could increase the validity and complexity of findings, as well as enabling better evaluation of interventions (Larson et al., 2015). Specifically applying intervention theory to a VR experience could help predict outcomes and guide measurement of effectiveness and impact through identifying appropriate variables and determinants within the behavioural framework (Michie et al., 2011; Wienrich et al., 2021).

Conspicuous in their absence across the included studies are psychological barriers to behaviour change. Including psychological barriers within both the

theoretical underpinning and variables measured could further increase the applicability of findings (Kollmuss and Agyeman, 2002; Gifford et al., 2011). Barriers can manifest as social barriers (i.e. lack of policy support, lack of responsibility taken by business and industry, lack of facilitating initiatives) and individual barriers (i.e. feelings of distance from the issue, notions of more immediate priorities (finances, family), uncertainty and cost) (Lorenzoni et al., 2007). Psychological barriers prevent behaviour change and can manifest as blocks and gaps in the behavioural process (Graves and Roelich, 2021). Psychological gaps can be conceptualised as a disconnect between behavioural determinants and outcomes (Wienrich et al., 2021), and can manifest through the 'value-action gap' (Blake, 1999), 'attitude-behaviour gap' (Siegel et al., 2018), 'knowledge-behaviour gap' (Frick et al., 2004), and psychological distance ((Spence et al., 2012). As VR is often lauded as a tool to overcoming psychological distance (Breves, 2020), more research on this assumption and mechanism should be conducted, as increasingly immersive experiences are not always followed by realistic psychological responses (Wilson and Soranzo, 2015).

The dominance of a small group of theoretical paradigms determines both the research questions asked, and how the research is conducted (i.e. what and how behaviour is measured), as each theory presents a certain conceptualisation of behaviour and behavioural determinants. This manifested as three key limitations in current research design; 1) a focus on small-scale, low impact behaviours, 2) a tendency towards the creation of new metrics as opposed to building on existing work, and 3) research is primarily conducted over small timeframes, without control conditions. These limitations provide suggestions and opportunity for future work, which are outlined in turn.

The research questions could be argued to often focus on a narrow part of behavioural process, and be context-specific. This is shown through the focus on small-scale behaviours (e.g. behaviours such as hot water usage (Bailey et al., 2015), or napkin usage (Ahn et al., 2014)). While valuable to expand our broad understanding of this relatively new research area, no extrapolation is possible beyond these small-scale, context-specific behaviours. Focussing on low-impact

behaviours (e.g. recycling), although logistically more practical to research, inhibits development of behavioural interventions designed to address high-impact behaviours (e.g. meat consumption, travel behaviours), which is needed to address the climate and ecological crises at the pace and scale required (Wynes and Nicholas, 2017).

In terms of how behavioural determinants and outcomes are measured, a huge array of tailored metrics individual to the study needs were identified. Some metrics were standardised (e.g. presence, body transfer), but behavioural determinants and behaviour were measured largely through novel metrics in each new study. The novelty of the research area potentially goes some way to explaining this as part of the research process (Yung and Khoo-Lattimore, 2019), however, this can result in work which is unable to build directly on previous research (Markle, 2013) due to findings which are not directly comparable.

Finally, the research designs were dominated by lab-based, short-term studies. The frequency of laboratory conditions used in research limits ecological validity and generalisability, despite ecological validity being a key advantage for the use of VR in research (Gillath et al., 2008). This is a common limitation across behavioural research, due to logistical issues in conducting realistic or real-world behavioural research which can lead to limited experimental control and a lack of longitudinal work (Fauville et al. 2020). The experimental design that a simulated, virtual environment can create is open to critique due to the applicability and replicability of the findings to the complex and unpredictable conditions outside a laboratory test. The lack of control groups or conditions used in the research designs across this research body limits causality attribution and extrapolation of trends beyond the scope of the individual studies (Abrahamse, 2016). Despite this, there are significant advantages to utilising VR to explore pro-environmental behaviour in laboratory conditions, such as real-time response data (Parsons, 2015), visualising future scenarios (Scurati et al., 2021) and enabling a safe space to experience otherwise dangerous, expensive or impossible situations (Bailenson, 2018).

The implications of a narrow selection of behavioural determinants being measured over limited timeframes are that potential behavioural processes such

as intention or value decay over time or spillover/rebound behaviours cannot be explored. Only two studies measured the effect at one-week post-intervention, and Ahn et al. (2014) found the decay rate of the IVE condition was much slower than print and video conditions, as the 'effect' was still present after a week, therefore this provides some indication of the effectiveness of the intervention over time. This dominance of low-impact behaviours and a lack of longitudinal studies, could also be explained by discipline-wide logistical challenges in impact-focused experimental behavioural research (Lange and Dewitte 2019; Nielsen et al. 2021). Moving towards high-impact behaviours, measured in ecologically valid conditions, over longer time periods could expand the relevance of findings and help push forward more ambitious behavioural interventions in practice.

4.4.1 Recommendations for researchers and practitioners

Synthesising this research has shown that there is a huge scope and potential for pro-environmental behavioural research using VR. Some best practice and future research recommendations are suggested:

1. Consider high-impact behaviours, measured longitudinally,
2. Include psychological barriers to behaviour change in conceptual frameworks of behaviour change,
3. Build on existing metrics and measures of behaviour,
4. Integrate, and experiment with, a broad range of theory either to test directly or to interpret findings (including intervention theory in order to glean real-world insights),
5. Recognise the positionality of the researchers and the participants.

4.4.2 Limitations

Methodological limitations of this research are created through the inflexibility of the systematic review. The highly interdisciplinary nature of the research area creates a risk that different lexicons across disciplines result in sections of literature being missed, however, the extensive scoping search should mitigate

this somewhat. Another limitation is the small sample size of this review, which identified 18 records for inclusion due to the novelty of the research area, however, the pilot study and repeated trialling of the review framework and quality appraisal can provide confidence that the conclusions reflect the current published knowledge.

4.4.3 Positionality

It is important to note that the perspective of the researcher significantly impacts the results, even within the context of a systematic review, as the researcher influences the data collected and its interpretation. Positionality should be more clearly recognized across systematic reviews in order to increase transparency and replicability. In this case, I bring an environmental/sustainability perspective, and with that bring assumptions. The focus of this review is on individual behaviour change, and works within the normative paradigm that individuals can collectively have a significant positive impact through direct change (i.e. consumption, purchasing) and indirect change (i.e. education, voting). However, the role that government and business have in restructuring and enabling pro-environmental behaviours should be recognised, and this work sits within the framework that system change can work in tandem with individual behaviour change. This extends to the theoretical discussion and fundamental underpinnings and assumptions of this work; broader systemic barriers to behaviour change cannot be overcome through individual-focused behavioural interventions such as VR. I recognise that and advocate that behavioural interventions are designed with broader systemic understanding of barriers to change in mind, through applying theory such as systems of provision (Bayliss et al., 2021), and considering fundamental issues such as equity, access and justice.

4.5 Conclusions

This paper outlines the state of research within the sphere of pro-environmental behaviour change research using VR. This is done through conducting a systematic review exploring the overarching question ‘how has virtual reality been used to research pro-environmental behaviour?. The systematic review methodology constitutes a key contribution of this work as a new framework for systematic reviews within environmental social sciences has been developed. Immersive technologies enable research which would otherwise be logistically challenging to be carried out. Research has been focused largely on the technical elements of an individual’s experience in VR (e.g. presence, immersion), with behaviour and behaviour change commonly explored through a linear understanding of behaviour, with measures centred around the same few behavioural determinants (e.g. environmental knowledge, awareness, behavioural intention). This research has primarily occurred over short timeframes, and focused on small-scale and low impact behaviours. This presents a number of areas for future research. A move towards longitudinal work could enable the effectiveness of interventions to be more fully evaluated. The use of metrics could focus on building knowledge though consistent application, moving away from a 'pick and choose' approach. The current theoretical paradigms could be limiting the behavioural determinants explored, therefore I recommend expanding this (especially to include psychological barriers) by capitalising further on the highly interdisciplinary nature of the research area is essential, to bring in knowledge and frameworks from across the disciplinary divides.

4.6 References

Abrahamse, W. 2016. Research Designs for Measuring the Effectiveness of Interventions In: Research Methods for Environmental Psychology [Online]. John Wiley & Sons, Ltd, pp.291–306. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119162124.ch15.

Ahn, S.J. 2011. Embodied Experiences In Immersive Virtual Environments: Effects On Pro-Environmental Attitude And Behavior.

Ahn, S.J., Bailenson, J.N. and Park, D. 2014. Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. Computers in Human Behavior. 39, pp.235–245.

Ahn, S.J., Le, A.M.T. and Bailenson, J. 2013. The Effect of Embodied Experiences on Self-Other Merging, Attitude, and Helping Behavior. Media Psychology. 16(1), pp.7–38.

Ahn, S.J.G., Bostick, J., Ogle, E., Nowak, K.L., McGillicuddy, K.T. and Bailenson, J.N. 2016. Experiencing Nature: Embodying Animals in Immersive Virtual Environments Increases Inclusion of Nature in Self and Involvement With Nature. Journal of Computer-Mediated Communication. 21(6), pp.399–419.

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes. 50(2), pp.179–211.

Bailenson, J. 2018. Experience on demand : what virtual reality is, how it works, and what it can do. W. W. Norton & Company.

Bailey, J.O., Bailenson, J.N., Flora, J., Armel, K.C., Voelker, D. and Reeves, B. 2015. The Impact of Vivid Messages on Reducing Energy Consumption Related to Hot Water Use. Environment and Behavior. 47(5), pp.570–592.

Ballantyne, A.G., Wibeck, V. and Neset, T.-S. 2016. Images of climate change – a pilot study of young people's perceptions of ICT-based climate visualization. Climatic Change. 134(1–2), pp.73–85.

Bayliss, K., Mattioli, G. and Steinberger, J. 2021. Inequality, poverty and the privatization of essential services: A 'systems of provision' study of water, energy and local buses in the UK. Competition & Change. 25(3–4), pp.478–500.

Blake, J. 1999. Overcoming the ‘value-action gap’ in environmental policy: Tensions between national policy and local experience. Local Environment. 4(3), pp.257–278.

Blascovich, J. and Bailenson, J. 2011. Infinite Reality: Avatars, Eternal Life, New Worlds, and the Dawn of the Virtual Revolution. William Morrow & Co.

Breves, P. 2020. Bringing People Closer: The Prosocial Effects of Immersive Media on Users’ Attitudes and Behavior. Nonprofit and Voluntary Sector Quarterly. 49(5), pp.1015–1034.

Calogiuri, G., Litleskare, S., Fagerheim, K.A., Rydgren, T.L., Brambilla, E. and Thurston, M. 2018. Experiencing Nature through Immersive Virtual Environments: Environmental Perceptions, Physical Engagement, and Affective Responses during a Simulated Nature Walk. Frontiers in Psychology. 8.

Calvi, L., Santos, C.P., Relouw, J., Endrovski, B., Rothwell, C., Sara, A., Lucrezi, S., Palma, M. and Pantaleo, U. 2017. A VR Game to Teach Underwater Sustainability while Diving In: 2017 Fifth IFIP Conference on Sustainable Internet and ICT for Sustainability. Sustainable Internet and ICT for Sustainability. New York: IEEE, pp.114–117.

Capstick, S., Lorenzoni, I., Corner, A. and Whitmarsh, L. 2014. Prospects for radical emissions reduction through behavior and lifestyle change. Carbon Management. 5(4), pp.429–445.

Cepok, J., Arzaroli, R., Marnholz, K., Grobe, C.S., Reuter, H., Nelson, K., Lorenz, M., Weller, R. and Zachmann, G. 2019. Effects of VR on intentions to change environmental behavior In:, pp.874–875. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071861024&doi=10.1109%2fVR.2019.8797849&partnerID=40&md5=c3661ce52605a307f474e92de8edd044.

Chirico, A., Scurati, G.W., Maffi, C., Huang, S., Graziosi, S., Ferrise, F. and Gaggioli, A. 2020. Designing virtual environments for attitudes and behavioral change in plastic consumption: a comparison between concrete and numerical information. Virtual Reality.

Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y. and Seto, K.C. 2016. Beyond Technology: Demand-Side Solutions for Climate Change Mitigation. Annual Review of Environment and Resources. 41(1), pp.173–198.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K.R., Ceron, J.P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V.R. and Sauerborn, R. 2019. It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. Energy Research & Social Science. 52, pp.144–158.

Fan, S., Zhang, Y., Fan, J., He, Z. and Chen, Y. 2010. The application of virtual reality in environmental education: Model design and course construction Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-77953314366&doi=10.1109%2fICBECS.2010.5462324&partnerID=40&md5=95649567b16d2fef632d112f83337691.

Fauville, G., Bailenson, J.N. and Queiroz, A.C.M. 2020. Virtual reality as a promising tool to promote climate change awareness In: J. Kim and H. Song, eds. Technology and Health. Elsevier, pp.91–108.

Frick, J., Kaiser, F.G. and Wilson, M. 2004. Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample. Personality and Individual Differences. 37(8), pp.1597–1613.

Gifford, R., Kormos, C. and McIntyre, A. 2011. Behavioral dimensions of climate change: drivers, responses, barriers, and interventions: Behavioral dimensions of climate change. Wiley Interdisciplinary Reviews: Climate Change. 2(6), pp.801–827.

Gillath, O., McCall, C., Shaver, P.R. and Blascovich, J. 2008. What can virtual reality teach us about prosocial tendencies in real and virtual environments? Media Psychology. 11(2), pp.259–282.

Graves, C. and Roelich, K. 2021. Psychological Barriers to Pro-Environmental Behaviour Change: A Review of Meat Consumption Behaviours. Sustainability. 13(21), p.11582.

Hartmann, P. and Apaolaza-Ibáñez, V. 2008. Virtual Nature Experiences as Emotional Benefits in Green Product Consumption: The Moderating Role of Environmental Attitudes. Environment and Behavior. 40(6), pp.818–842.

Hsu, W.-C., Tseng, C.-M. and Kang, S.-C. 2018. Using Exaggerated Feedback in a Virtual Reality Environment to Enhance Behavior Intention of Water-Conservation. Educational technology and society. 21(4, SI), pp.187–203.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research. 8(3), pp.239–260.

Kort, Y.A.W. de, IJsselsteijn, W.A., Kooijman, J. and Schuurmans, Y. 2003. Virtual Laboratories: Comparability of Real and Virtual Environments for Environmental Psychology. Presence: Teleoperators and Virtual Environments. 12(4), pp.360–373.

Lange, F. and Dewitte, S. 2019. Measuring pro-environmental behavior: Review and recommendations. Journal of Environmental Psychology. 63, pp.92–100.

Larson, L.R., Stedman, R.C., Cooper, C.B. and Decker, D.J. 2015. Understanding the multi-dimensional structure of pro-environmental behavior. Journal of Environmental Psychology. 43, pp.112–124.

Linowes, J. 2015. Unity Virtual Reality Projects [Online]. United Kingdom: Packt Publishing. Available from: https://books.google.co.uk/books?id=vuF5CgAAQBAJ.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. Global Environmental Change. 17(3–4), pp.445–459.

Markle, G.L. 2013. Pro-Environmental Behavior: Does It Matter How It's Measured? Development and Validation of the Pro-Environmental Behavior Scale (PEBS). Human Ecology. 41(6), pp.905–914.

Markowitz, D.M., Laha, R., Perone, B.P., Pea, R.D. and Bailenson, J.N. 2018. Immersive Virtual Reality field trips facilitate learning about climate change. Frontiers in Psychology. 9(NOV).

Mayer, F.S. and Frantz, C.M. 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology. 24(4), pp.503–515.

Michie, S., van Stralen, M.M. and West, R. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science : IS. 6, p.42.

Michie, S.F., West, R., Campbell, R., Brown, J. and Gainforth, H. 2014. ABC of behaviour change theories. Silverback Publishing.

Mohamed Elias, Z., Batumalai, U.M. and Azmi, A.N.H. 2019. Virtual reality games on accommodation and convergence. Applied Ergonomics. 81, p.102879.

Nelson, K.M., Anggraini, E. and Schlüter, A. 2020. Virtual reality as a tool for environmental conservation and fundraising. Plos one. 15(4), p.e0223631.

Nicholson-Cole, S.A. 2005. Representing climate change futures: a critique on the use of images for visual communication. Computers, Environment and Urban Systems. 29(3), pp.255–273.

Nielsen, K.S., Cologna, V., Lange, F., Brick, C. and Stern, P.C. 2021. The case for impact-focused environmental psychology. Journal of Environmental Psychology. 74, p.101559.

Nim, H.T., Wang, M., Zhu, Y., Sommer, B., Schreiber, F., Boyd, S.E. and Wang, S.J. 2016. Communicating the effect of human behaviour on the great barrier reef via mixed reality visualisation In: Big Data Visual Analytics (BDVA), 2016. IEEE, pp.1–6.

Oh, C.S., Bailenson, J.N. and Welch, G.F. 2018. A Systematic Review of Social Presence: Definition, Antecedents, and Implications. Frontiers in Robotics and AI. 5(114), pp.1–35.

Pan, X. and Hamilton, A.F. de C. 2018. Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. British Journal of Psychology. 109(3), pp.395–417.

Pan, Y. and Steed, A. 2019. How Foot Tracking Matters: The Impact of an Animated Self-Avatar on Interaction, Embodiment and Presence in Shared Virtual Environments. Frontiers in Robotics and Ai. 6, p.104.

Parsons, T.D. 2015. Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. Frontiers in Human Neuroscience. 9.

Petersen, G.B., Klingenberg, S., Mayer, R.E. and Makransky, G. 2020. The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. British Journal of Educational Technology. 51(6), pp.2098–2114.

Pimentel, D., Amaya, R., Halan, S., Kalyanaraman, S. and Bailenson, J. 2019. Climate change on your plate: A VR seafood buffet experience In:, pp.1120–1121. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071834990&doi=10.1109%2fVR.2019.8798076&partnerID=40&md5=5a87c565e6a5e27456869a79d987a879.

Queiroz, A.C.M., Kamarainen, A.M., Preston, N.D. and Leme, M.I. da S. 2018. Immersive Virtual Environments and Climate Change Engagement In: iLRN 2018 Montana [Online]. Verlag der Technischen Universität Graz. [Accessed 14 December 2020]. Available from: https://openlib.tugraz.at/ilrn-2018-montana-2018.

Raja, U.S. and Carrico, A.R. 2021. A Qualitative Exploration of Individual Experiences of Environmental Virtual Reality Through the Lens of Psychological Distance. Environmental Communication. 15(5), pp.594–609.

Rambach, J., Lilligreen, G., Schäfer, A., Bankanal, R., Wiebel, A. and Stricker, D. 2020. A survey on applications of augmented, mixed and virtual reality for nature and environment. arXiv:2008.12024 [cs].

Rees, R., Oliver, K., Woodman, J. and Thomas, J. 2009. Children's views about obesity, body size, shape and weight: a systematic review. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Ruscio, D., Caruso, G., Mussone, L. and Bordegoni, M. 2018. Eco-driving for the first time: The implications of advanced assisting technologies in supporting pro-environmental changes. International Journal of Industrial Ergonomics. 64, pp.134–142.

Scurati, G.W., Bertoni, M., Graziosi, S. and Ferrise, F. 2021. Exploring the Use of Virtual Reality to Support Environmentally Sustainable Behavior: A Framework to Design Experiences. , p.20.

Sheppard, S.R. 2005. Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. Environmental Science & Policy. 8(6), pp.637–654.

Siegel, L., Cutter-Mackenzie-Knowles, A. and Bellert, A. 2018. Still 'Minding the Gap' Sixteen Years Later: (Re)Storying Pro-Environmental Behaviour. Australian Journal of Environmental Education. 34(2), pp.189–203.

Soliman, M., Peetz, J. and Davydenko, M. 2017. The impact of immersive technology on nature relatedness and pro-environmental behavior. Special Issue: New Evidentiary Standards for the Science of Technology and Human Behavior. 29(1), pp.8–17.

Spence, A., Poortinga, W. and Pidgeon, N. 2012. The Psychological Distance of Climate Change. Risk Analysis. 32(6), pp.957–972.

Steg, L. and Vlek, C. 2009. Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology. 29(3), pp.309–317.

Stern, P.C. 2020. A reexamination on how behavioral interventions can promote household action to limit climate change. Nature Communications. 11(1), p.918.

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A. and Kalof, L. 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review. 6(2), p.17.

Wang, K., Tekler, Z.D., Cheah, L., Herremans, D. and Blessing, L. 2021. Evaluating the Effectiveness of an Augmented Reality Game Promoting Environmental Action. Sustainability. 13(24), p.13912.

Wienrich, C., Döllinger, N. and Hein, R. 2021. Behavioral Framework of Immersive Technologies (BehaveFIT): How and Why Virtual Reality can Support Behavioral Change Processes. Frontiers in Virtual Reality. 2.

Wilson, C.J. and Soranzo, A. 2015. The Use of Virtual Reality in Psychology: A Case Study in Visual Perception. Computational and mathematical methods in medicine.

Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environmental Research Letters. 12(7), p.074024.

Yung, R. and Khoo-Lattimore, C. 2019. New realities: a systematic literature review on virtual reality and augmented reality in tourism research. Current Issues in Tourism. 22(17), pp.2056–2081.

4.7 Bridging discussion

Several components of this work guided decisions for Phase 2 and 3 of this research. Conceptually, the systematic review found a research focus on small scale, low impact behaviours which tended to be measured over a short time period. This determined the focus on high-impact behaviours across both Phase 2 and 3, as well as the focus on meat consumption as a high-impact behaviour in Phase 2. The systematic review found a focus on experiential and technical factors which affect the outcomes of an environmental-themed intervention, with less research focusing on behavioural determinants and outcomes. Therefore, Phases 2 and 3 focus more on behavioural determinants, outcomes and barriers than technical and experiential components of VR. The studies included in the systematic review sparsely utilised behavioural theory explicitly in relation to the study designs, therefore Phase 2 focused on the use of theory in pro-environmental behaviour as a key research question. Additionally, Phase 3 centred theory within the research design and analysis, utilising the Kollmuss and Agyeman (2002) model of pro-environmental behaviour to determine which components of behaviour to measure. Methodologically, the critiques I identified in the studies included in this systematic review informed the experimental design within Phase 3. The prominence of pre-experimental and quasi-experimental designs helped determine the decision to construct a true experimental design, with random allocation of participants and a control group. The use of bespoke metrics which lead to difficulty in building knowledge and comparing like for like determined the decision to utilise existing validated metrics as far as possible.

It is worth noting that Phase 2 of this research was conducted during the early stages of the pandemic. The original research design involved moving straight to the experimental phase, conducting in-person experiments across Leeds, with a third phase involving follow-up interviews with participants. When this became impossible due to lockdown, the second phase of this research was re-designed to become a desk-based literature review. This builds on Phase 1 by addressing some research gaps identified, primarily through focusing on a high-impact behaviour, through the lens of psychological barriers.

Chapter 5 Psychological Barriers to Pro-Environmental Behaviour Change: A Review of Meat Consumption Behaviours

This chapter has been published in 'Sustainability' in October 2021 as:

Graves, C. and Roelich, K. 2021. Psychological Barriers to Pro-Environmental Behaviour Change: A Review of Meat Consumption Behaviours. Sustainability. 13(21), p.11582.

Some minor amendments have been made to that text to enable clear links to the rest of the thesis.

Abstract

Meat consumption behaviours contribute significantly to global greenhouse gas emissions. Interventions to enable meat consumption reductions need to consider the psychological barriers preventing behavioural changes. Our aims were twofold; 1) to explore the psychological barriers to reducing meat consumption and how they can be overcome, and 2) to explore the usefulness of integrating the Kollmuss and Agyeman (2002) model of pro-environmental behaviour and psychological distance, which provides the analytical framework for the Rapid Evidence Review. This review utilised three databases, focussing on empirical studies since 2010, which returned 277 results with 7 eligible studies. We found that habit is the most significant psychological barrier to change, however values and attitudes could act as moderating variables. We found gaps in the behavioural mechanism, indicating the presence of direct and indirect psychological barriers. We identify several actionable policy recommendations, such as utilising co-benefits, the importance of values in messaging, and targeting repeated behaviours. We found that study outcomes did not always translate into policy recommendations and were limited by existing policy paradigms. We found that the Kollmuss and Agyeman (2002) model of pro-environmental behaviour and psychological distance can be integrated effectively to create a comprehensive analytical framework. This comprehensiveness suggests that integrating psychological distance across pro-environmental behavioural research and policy could improve the effectiveness of interventions, and is worthy of future research.

The abstract is written in the collective 'we' as it was in the published version. The remainder of the chapter has been edited to be written in 'I' or passive voice.

5.1 Introduction

The climate impact of food and agriculture more broadly, is estimated to account for 19-29% of global greenhouse gas (GHG) emissions (Vermeulen et al., 2012), with livestock alone accounting for 18% of total GHG emissions (Steinfeld et al., 2006). Emissions associated with food supply is a universal issue, however, accountability for unsustainable meat consumption lies predominantly with the most developed nations. Meat consumption in the UK has been estimated at 81.5kg/year/person, well above the global average of 43kg/year/person (Ritchie, 2017). Reducing meat consumption through shifting to a plant-based diet, finding meat alternatives or simply reducing meat consumed can have a significant impact on an individuals' and national emissions profile.

Existing research has been conducted around motivators, drivers, attitudes, intervention studies, and environmental and contextual barriers (such as cost, availability, culture (e.g. Brunelle *et al*., 2017 (Brunelle et al., 2017); Kemper, 2020 (Kemper, 2020)), in relation to meat consumption behaviours. Factors such as the environmental and climate impacts of meat (e.g. Girod *et al*., 2014 (Girod et al., 2014; Graça et al., 2019)); motivations and attitudes around reducing meat consumption (e.g. Clonan *et al*., 2015 (Clonan et al., 2015); Lentz *et al*., 2018 [9]); the role of external factors (Stoll-Kleemann and Schmidt, 2017); and the effects of different interventions (Bianchi, Dorsel, et al., 2018; Taufik et al., 2019) have been considered. Existing work has focused on how to encourage meat consumption reductions (e.g. Stevens, 2017; Lorenz and Langen, 2018; Taufik *et al*., 2019 (Stevens, 2017; Lorenz and Langen, 2018; Taufik et al., 2019)), however more research on the psychological barriers blocking or hindering meat consumption reduction is needed to ensure interventions are as effective as possible (Çoker and van der Linden, 2020). To our knowledge, no systematic or rapid evidence review has solely focussed on psychological barriers to behaviour change.

Psychological barriers are factors within a behavioural mechanism which prevents a different or new behaviour from occurring (Lacroix et al., 2019). An example of this could be blocking new knowledge due to existing emotional attachment. The importance of psychological barriers to reducing meat consumption should not be ignored. Barriers could explain the gap between attitude and intention (Lentz et al., 2018; Lacroix et al., 2019), or intention and behaviour (Grimmer and Miles, 2017), or other gaps which prevent a pro-environmental behaviour occurring, which cannot be explained by an absence of behavioural determinants. There is need for more research around

psychological barriers to changing high-impact behaviours (Poortinga et al., 2004; Gifford, 2011), including meat consumption, which is an important high impact behaviour in terms of per capita emissions (Wynes et al., 2018).

Research on 'spillover' behaviours suggests overcoming barriers to one pro-environmental behaviour, such as reducing meat consumption, can have co-benefits across other behavioural domains (Lanzini and Thøgersen, 2014; Capstick et al., 2019). Solely considering behavioural determinants and drivers within research and policy risks missing significant emissions mitigation potential, through ineffective policy resulting in sub-optimal behavioural shifts or potential rebound effects (Grabs, 2015). Overcoming psychological barriers to meat consumption reduction could provide a long-term strategy to achieving a variety of policy aims, extending beyond climate and environmental policy.

Despite widespread political and public understanding of the need to alter individual and household behaviours to mitigate climate change, behavioural change policy is muted and unambitious due to the focus on technocratic policy options (Dietz et al., 2009). Policy remains focused on encouraging or facilitating behaviour through drivers as opposed to targeting barriers to overcome. Most policies relating to pro-environmental behaviour are focused on knowledge transfer or awareness raising (Gifford and Chen, 2017), despite the information deficit model being widely understood to be too simplistic (McKenzie-Mohr, 2000). Two types of messaging for awareness-raising are commonly applied in meat consumption interventions; health and moral concerns, however disgust (emotion) was found to be at least, if not a more effective message (Palomo-Vélez et al., 2018), as health messages are often misunderstood (Lea et al., 2006).

As psychological barriers to reducing meat consumption are under-researched and under-utilised within policy, compared to behavioural determinants, a rapid evidence review is appropriate to synthesise existing evidence on how psychological barriers prevent meat consumption reduction. Barriers to behaviour change are increasingly being included in studies on meat consumption reduction, but often alongside drivers (Stoll-Kleemann and Schmidt, 2017), and often are conceptualised as the absence of drivers. This chapter explores barriers as independent behavioural variables in their own right. 'External' barriers – for instance; the cost of meat alternatives, availability of alternatives, etc. - are excluded to focus on psychological processes and barriers such as the role of emotional attachment, habit and values. This research uses two frameworks as the theoretical foundation and analytical framework in which to explore the psychological barriers to reducing meat

consumption; the Kollmuss and Agyeman (Kollmuss and Agyeman, 2002) model and Psychological Distance.

5.1.1 Aims and research questions

A rapid evidence review enables a rigorous yet time-efficient method of evidence synthesis around a focussed issue, structured around three Research Questions:

> RQ4: How can psychological barriers to pro-environmental behaviour change affect meat consumption in individuals?
>
> RQ5: How does psychological distance manifest as a barrier to meat consumption reduction?
>
> RQ6: How can these psychological barriers be overcome?

Firstly, the theoretical grounding is detailed which provides the analytical framework for the review. The rapid evidence review methodology is then outlined before analysing the findings within the framing of the theoretical integration, structured through the three research questions. The discussion primarily focusses on the third research question; how to overcome the psychological barriers to meat consumption reduction. This followed by recommendations for policy and research, and reflections on the usefulness and application of the theoretical framework.

5.2 Methods

5.2.1 Theoretical grounding

Behavioural theory guides much of the existing research on meat consumption behaviours, as it determines (explicitly or implicitly) how behaviour is researched and what factors are included. Factors such knowledge, values, attitudes, are nearly always included in studies. Fewer studies also include norms (following the Value-Belief-Norm Theory (Stern et al., 1999)), perceived behavioural control (following the Theory of Planned Behaviour (Ajzen, 1991)), habits (e.g. Verplanken and Roy, 2016 (Verplanken and Roy, 2016)), emotion (e.g. Palomo-Vélez *et al*., 2018 (Palomo-Vélez et al., 2018)), or awareness (e.g. Clonan *et al*., 2015 (Clonan et al., 2015); Lentz *et al*., 2018 (Lentz et al., 2018)). Research integrating barriers of any kind is limited (e.g. Gifford, 2011 (Gifford, 2011)), and behavioural models mirror the dominance within the pro-environmental behaviour literature by focusing on *determinants* of behaviour only. Research across food or health disciplines favours differing theories to sustainability or climate disciplines researching similar issues, such as the Protection Motivation Theory (Rogers, 1975) instead of the Theory of Planned Behaviour.

Pro-environmental behaviour change can be viewed as a dynamic process, whereas most models commonly applied do not consider the process after the 'action' or behaviour change has occurred (Poortinga et al., 2004). The models are generally linear structures (e.g. Value-Belief-Norm Theory (Stern et al., 1999); Theory of Planned Behaviour (Ajzen, 1991)), which could be due to the lack of longitudinal studies on actual behaviour; either observed or self-reported.

5.2.1.1 Kollmuss and Agyeman (2002) model of pro-environmental behaviour

Kollmuss and Agyeman (2002) explored the gap between knowledge/awareness and behaviour, and proposed a model with behavioural determinants, and barriers that block the path to behaviour change. This model brought together behavioural factors and models across psychology and sociology (see **Figure 7**). The novelty in the model is largely based around the explicit use and placement of barriers within the framework of behavioural determinants.

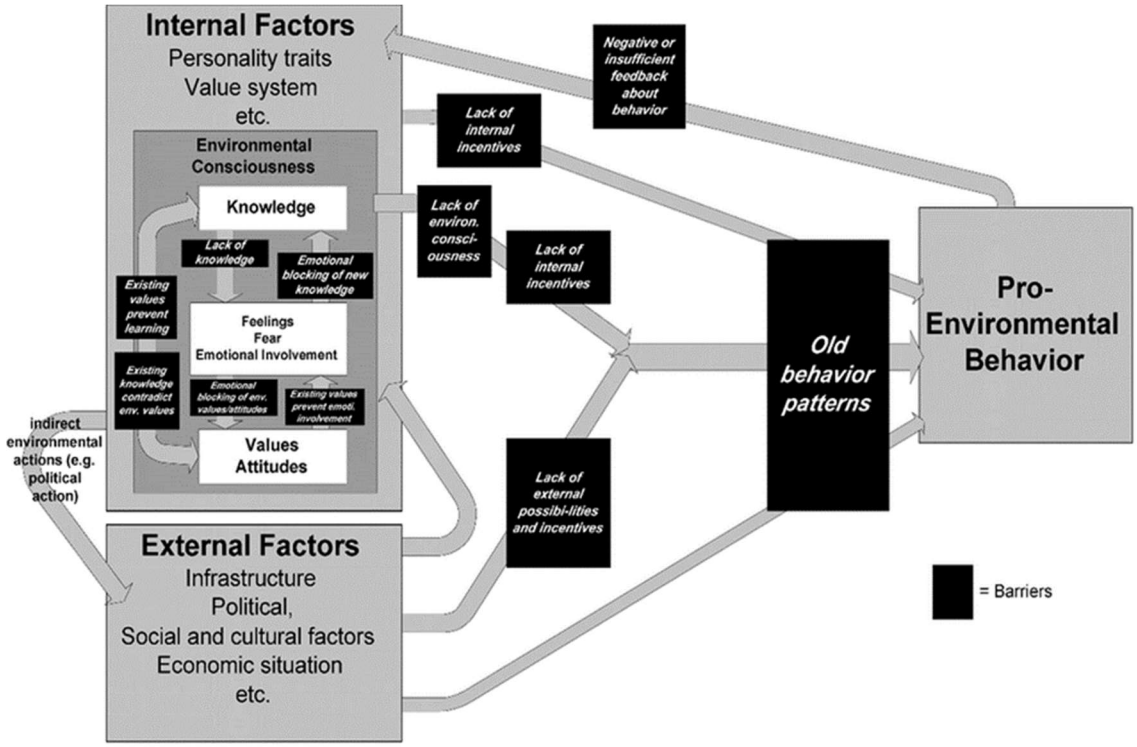


Figure 7 Kollmuss and Agyeman (2002) model of pro-environmental behaviour

The Kollmuss and Agyeman (2002) (K&A) study became a seminal work within pro-environmental behaviour change literature; however, it is not without critique due to the sheer breadth of the model. Complexity is the most prominent critique - as a wide array of perspectives have been integrated into a relatively deductive framing (Payne, 2002). This model was selected as the analytical framework for this research due to its breadth, however that comes at the cost of contextual complexity. However, what Kollmuss and Agyeman (2002) do not conceptualise is the notion of gaps and distances within the behavioural process, which potentially could exclude significant elements of an individual's behaviour change process, rendering subsequent findings and/or policy recommendations ineffective. Therefore, psychological distance is identified as a complementary concept to integrate in the analytical framework, to address this.

5.2.1.2 Psychological distance

Psychological distance is rooted in risk literature (Leiserowitz, 2005), and is defined as "an individual's perception of how removed an object, risk, or event is from that individual" (Leiserowitz, 2005, p. 94). Within the context of climate

change, this generally manifests as proximity relating to concern, willingness and action (McDonald et al., 2015), and this can manifest consciously and unconsciously. Trope and Liberman (2010a, p9) proposed the Construal Level Theory which outlines four dimensions of psychological distance; “in time, in space, in social distance, and in hypotheticality”, which Spence *et al.* (2012) apply to climate change specifically, and interpret as spatial, social, uncertainty and temporal distances. Loy and Spence (2020) identified two strategies for overcoming psychological distance - ‘proximising’ (focusing on local impacts) and ‘bridging’ (increasing the notion of global identity), both are found to reduce the psychological distance perceived.

5.2.2 Theoretical integration

This research combines these two understandings of psychological barriers into an analytical framework. Kollmuss and Agyeman (2002) specifically identify how barriers interact with behavioural determinants, whereas most models focus on determinants as proxies for barriers. The notion of the gap between concern and behaviour identified in Kollmuss and Agyeman (2002) can be considered conceptually similar to psychological distance - the idea that gaps (or distances) between and within elements of our understandings prevents behaviour change. These two frameworks can be used as the lenses through which to examine the data in order to interrogate both the data set and the frameworks themselves, , as integrating theoretical framings can assist in creating more effective interventions (Klöckner, 2013).

5.2.3 Rapid evidence review

The Rapid Evidence Review (RER) protocol was developed in February 2020, with data collection conducted between February – May 2020, in response to a policy need from DEFRA (the Department for Environment, Food, and Rural Affairs). DEFRA requested a policy-relevant synthesis on meat consumption behaviours to inform future intervention strategy. Rapid evidence reviews are a systematic and rigorous method to address a specific research question, often used to develop timely syntheses for policy evaluation or proposals.

A time-stamped copy of the protocol is registered in Open Science Framework (DOI 10.17605/OSF.IO/URW64). Full details of this methodology is outlined in Chapter 3: Methods and supplementary details can be found in Appendix B.

5.3 Results

5.3.1 Study design synthesis

Seven articles were included in this Rapid Evidence Review: four quantitative, two qualitative and one mixed-methods research design (Table 6). The studies all measure similar dependent variables; (self-reported) behaviour, intention, awareness/attitudes around reducing meat consumption. None of the studies looked exclusively at psychological barriers and psychological barriers were often included alongside external barriers (i.e. availability, price of meat-alternatives etc.). Three studies explore psychological barriers directly (i.e. use specific metrics); as two use other determinants as proxies for barriers (i.e. absence of motivation, agency, self-efficacy etc.), and the two qualitative studies draw out narrative themes in relation to psychological barriers. All studies were conducted in Europe, Australia or the US, so socio-demographic and cultural limitations need to be recognised. The discourse varies, as studies are split across 'reducing meat consumption' (3 studies), 'adopting a plant-based diet' (2), 'alternatives to meat' (1) and 'climate-friendly food choices' (1).

Five studies performed well in the critical appraisal (CA) in terms of rigour and clarity of evidence presented (Hoe17 (Hoek et al., 2017); Hun16 (Hunter and Roos, 2016); Mak14 (Makiniemi and Vainio, 2014); Poh15 (Pohjolainen et al., 2015); Urb20 (Urbanovich and Bevan, 2020)). Two studies scored poorly (Cir19 (Circus and Robison, 2019); Kem20 (Kemper, 2020)), however, as this was assessed to be due to the lack of evidence presented as opposed to poor research design, all papers are weighted equally. There is a general issue of external validity, as is common across behavioural studies.

Reference	Code	Research Question	Study design	Study outcomes	Role of psychological barriers
Circus and Robison (2019)	CIR19	Consumer perceptions of sustainable protein	Mixed (interviews; survey)	Plant-based substitutes preferred	Moral and ethical reasons are barriers and drivers
Hoek *et al*., (2017)	HOE17	Attitudes, experience, perception of sustainable food choices	Qualitative (in-depth interviews)	Motivation discrepancy: 'reduce meat consumption' and ‘increase plant-based diet’	Habit biggest barrier, health second most prevalent. Low awareness of environmental impact of meat.
Hunter and Roos (2016)	HUN16	Meat consumption reduction motivations	Quantitative (survey)	Higher self-efficacy increases adoption of alternatives	Perceived difficulty of new behaviour and knowledge of climate impact most significant. Threat other vs. threat close.
Kemper (2020)	KEM20	Lifecycle stage variation in reduction of meat consumption	Qualitative (focus groups)	Barriers act across demographics. Culture and values affect reductions	Health can be barrier or motivator. Knowledge: low effect. Enjoyment and values barriers
Makiniemi and Vainio (2014)	MAK14	Comparison of self-perceived barriers and self-reported behaviour	Quantitative (survey)	Dissociation of self-perception of barriers and behaviours	Lack of knowledge *perceived* as biggest barrier. Habit and disbelief in climate impact most significant
Pohjolainen *et al*. (2015)	POH15	Prevalence of barriers to plant-based diet	Quantitative (survey)	Barriers work together to form one "barrier dimension"	Enjoyment is biggest barrier, then familiarity, and

					perception of health benefits. Difficulty important
Urbanovich and Bevan (2020)	URB20	Most common self-reported barriers and benefits of plant-based diet	Quantitative (survey)	Norms, habits, self-efficacy are moderating variables	Habits biggest barrier. Norms biggest predictor of behaviour

Table 6 Summary table of included studies, including reference code, study design, headline findings, and critical appraisal

5.3.2 Research Question 4: How can psychological barriers to pro-environmental behaviour change affect meat consumption in individuals?

Using the Kollmuss and Agyeman (2002) model as the framework with which to analyse the outcomes from each study, specific barriers are grouped thematically (by values, emotions, knowledge and habit). Habits were found to be the most significant and frequently identified barrier, and values and attitudes were often identified as co-variates to other barriers.

5.3.2.1 Habit

Habits were identified as the most significant barrier in three of the studies (Hoe17, Mak14, Urb20), with a fourth (Poh15) identifying habit as the strongest predictor of a 'barrier effect', and a fifth (Kem20) relating habit and difficulty. Despite the small sample size of studies, this provides interesting insight. Habits are often referred to explicitly (or discussed as 'existing behaviour' or 'behavioural patterns'). This could affect its prominence in the results as other barriers have a higher degree of subjectivity involved. Habit could be linked to difficulty in changing behaviour (Kem20), familiarity with meat eating behaviour (Poh15), and potentially perceptions of 'unnaturalness' (Cir19) (in relation to lab-grown alternatives).

5.3.2.2 Values and attitudes

Values and attitudes were not identified as a significant barrier to behaviour change, but were discussed extensively in five studies. Values were much more widely referenced than attitudes. Values relate to emotion, especially through cultural norms (Hoe17, Urb20) and heritage (Poh15, Kem20). An attitudinal dichotomy was identified (Cir19, Hoe17) between discourses of 'reducing meat consumption' (negative) and 'increasing plant-based diet' (positive). Moral and ethical reasons were classified as a values-related barrier although it could be argued there is a psychological distance-related component within those considerations, i.e. distance between self-animal-food. Perhaps surprisingly, moral and ethical reasons were only discussed in two studies (Cir19 and Urb20) and neither found ethical issues a dominant barrier to behaviour change. Values are linked to emotion and norms, without themselves being the most significant

barrier. This suggests values/attitudes act as covariates or moderating variables, therefore their relative importance may not be fully recognised within these studies.

5.3.2.3 Emotion

Emotional factors were identified as barriers in four studies, with one (Poh15) categorising enjoyment of meat as the most significant barrier to change. Cir19 explored this concept explicitly in their research and found meat attachment affected preference and willingness to consume alternative diets (lab grown meat, meat substitutes, insects). Attachment to meat is discussed almost interchangeably with enjoyment of meat across all studies, which complements Hun16's question of 'what the emotional cost of *not* eating meat is?'. Only one emotional positive from reducing meat consumption was discussed, where Hoe17 identified individuals 'feeling better about themselves' when eating a plant-based diet. Emotional barriers are found to be linked to values, such as associations with childhood (Kem20) and notions of cultural norms (Hoe17).

5.3.2.4 Knowledge

Knowledge was discussed as a barrier in five studies and identified as a significant barrier in Hun16. The common theme was 'understanding of the environmental impact of meat consumption' (Hoe17, Hun16, Kem20), but knowledge of climate friendly foods (Mak14) and nutritional information (Urb20) also appear. Although it appears as a barrier in five studies, Kem20 finds knowledge has a low effect on motivation to overcome barriers.

The interrelationships and interdependencies with and between the barriers are apparent throughout. No barrier exists in isolation, which supports the conceptualisation of barriers and the broader behavioural process discussed in Kollmuss and Agyeman (2002) and Poh15's discussion of the usefulness of a holistic 'barrier concept'. The four categories within Kollmuss and Agyeman (2002) capture a significant proportion of the study outcomes, however the remaining study outcomes around psychological barriers are further explored using psychological distance.

5.3.3 Research Question 5: How does psychological distance manifest as a barrier to meat consumption reduction?

The remaining study outcomes which did not fit into the Kollmuss and Agyeman (2002) model were coded for references to distances (conceptual or literal), gaps or other types of disconnection, which fitted within the understanding of psychological distance. The data extracted was categorised within the four elements of psychological distance (social, spatial, temporal, uncertainty) (Spence et al., 2012). This proved more subjective than categorising barriers within the Kollmuss and Agyeman (2002) model, as psychological distance is not a concept explicitly referenced in the included studies.

The two main findings were that 'social' and 'uncertainty'-related distances dominated the study outcomes, and that social distance did not manifest as expected based on current understandings of psychological distance. No outcomes were specifically categorised as 'temporal' psychological distance, and 'spatial' psychological distance only was assigned one outcome (**Figure 8**). 'Understanding of the severity and vulnerability to climate change' cuts across all types of psychological distance, and is a broad theme that could link to many of the previously identified barriers (e.g. knowledge, threat).

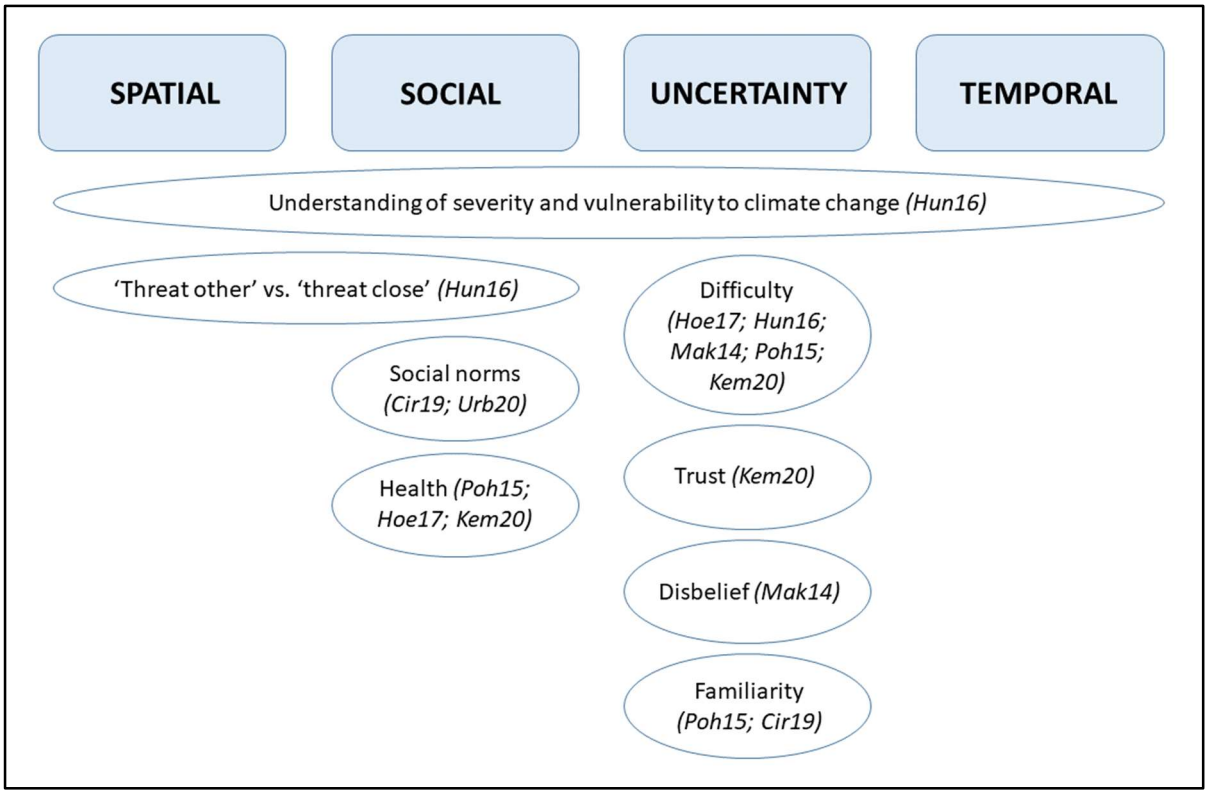


Figure 8: Study outcomes categorised by type of psychological distance

The findings identify psychological closeness/proximity as the dominant dimension of social distance. Increased social distance was not identified as a barrier to reducing meat consumption, as individuals advocated for behaviour in others that they themselves would apply (Cir19), and Hun16 identified 'threat other' (from climate change) as a smaller barrier to change than 'threat close'. This contradicts the common assumption within psychological distance that the further from the 'self' the issue is, the less the self will care or change behaviour. However, study outcomes which conceptualised the issue as close to the self (close psychological distance), for instance through health (Hoe17, Kem20, Poh15) and the effect of social norms (Urb20), found those to have a positive effect on overcoming barriers to change. These findings raise the issue that norms are not explicitly explored in Kollmuss and Agyeman (2002), which could indicate a gap, due to the prominence in other models (i.e. Value-Belief-Norm Theory (Stern *et al*., 1999 (Stern et al., 1999), and the General Model of Social Dilemmas (Gifford, 2006)). The findings suggest that dimensions of social distance can be categorised as both barriers and solutions to overcoming barriers.

Five study outcomes were categorised as 'uncertainty'. Difficulty was identified in five studies, and has been categorised as uncertainty as it related to a lack of nutritional understanding (Urb20), skills required (Hun16, Kem20), and to a gap between the perceived difficulty of consuming less meat/eating a plant-based diet, and the actual difficulty (Hoe17). 'Disbelief in climate impact' (Mak14, Urb20) is a theme that could be based on low knowledge of environmental impact (as in Kollmuss and Agyeman (2002)), and/or be a manifestation of psychological distance. Difficulty and disbelief occur alongside knowledge gaps, in relation to nutritional literacy and understanding of the climate impact of meat. Disassociation between the self-perception of barriers and actual barriers that Mak14 identified, could explain this. Mak14 found that disbelief was a significant self-perceived barrier, whereas lack of knowledge was identified as the third most relevant actual barrier. This indicates that other barriers affect disbelief (i.e. values), or that disbelief is not as significant as it is perceived within the individual.

Psychological distance revolves entirely around the self, i.e. the gap between the self and climate impacts, the self and wider social norms, and the self and perception of self. These findings indicate that distances manifesting as 'uncertainty' present barriers to changing meat consumption behaviour, whereas social distance presented a much more nuanced picture; and could be utilised for behavioural interventions.

5.3.3.1 Outliers

Three barriers do not neatly fit in either the Kollmuss and Agyeman (2002) model or psychological distance:

- Self-efficacy
- Self-perception of barriers and behaviour
- Gap between perception of ‘reducing meat consumption’ and ‘increasing plant-based diet’.

All three manifest as a gap between elements of the behavioural process. Self-efficacy could be conceptualised as a gap between behavioural determinants and agency. The gap between the perception of both barriers and behaviour can occur at any stage of the behavioural process and prevent a new behaviour from occurring. The difference in perception based on the framing of either ‘reducing meat consumption’ or ‘increasing plant-based diet’ could relate to a gap between emotion (e.g. meat attachment) and values (e.g. resentment about reducing/limiting behaviour). All three are rooted in the gap between an individual’s perception of self or their perception of the issue; and the reality (be that their actual behaviour, or their ability to change behaviour).

5.3.4 Research Question 6: How can these psychological barriers be overcome?

In order to explore how the barriers could be overcome, the policy recommendations from the studies were coded inductively, which resulted in four themes:

- The importance of messaging and framing
- Co-benefits with other issues (predominantly health)
- The use of knowledge and information
- The role of theory

The most frequently recommended action is for appropriate and tailored messaging and framing, with five studies focusing on that as a key strategy. This should be tailored to values and norms, otherwise it risks being counterproductive (i.e. high meat attachment individuals resisting a plant-based diet; meat alternatives would be more appropriate (Cir19)). Messaging could be targeted at those more sympathetic to changing behaviour (Poh15), different stages of the 'meat reduction journey' (Kem20), using multiple approaches to change behaviour (Hoe17), and targeting different drivers (Cir19). Using 'co-benefits' such as health (Hoe17) and food waste (Mak14), as the dominant policy framing or as part of a multi-pronged approach is also related to framing. Poh15 advocates for policy that cuts across issues to maximise effectiveness. The use of knowledge and information emerged, in relation to raising awareness of the climate impact of food (Hun16, Mak14), skills for reducing meat consumption (Kem20), and nutritional literacy (Urb20). Role of theory is advocated both implicitly and explicitly, with Urb20 recommending Social Judgement Theory, due to identifying a barrier linked to others' beliefs. Nudge Theory is advocated implicitly in three studies (Hoe17, Hun16, Urb20) by recommending focusing on small behavioural steps to potentially overcome perceived 'difficulty'. This assumes the 'difficulty' barrier corresponds to large or significant behavioural changes, and that smaller, 'achievable' nudges would be more effective, however this was not shown in any studies. This indicates a discrepancy between the study outcomes and subsequent policy recommendations intended to overcome these barriers, so this was explored further.

Policy recommendations such as education and information strategies clearly link directly to the knowledge barrier in Kollmuss and Agyeman (2002). Framing and messaging relate directly to value and attitude barriers. Some elements of psychological distance are addressed through framing, knowledge of climate

impacts, and some strategies relating to co-benefits (i.e. health). However, there were examples where there appeared to be a broken link between the study findings and the recommendations. Table 7 highlights the barriers that are not addressed through the policy recommendations. Difficulty and habit are most commonly not addressed explicitly in recommendations. Despite habit being categorised as a barrier in five of the studies, it is specifically referenced in the policy recommendations in only one study (Mak14: increase availability to overcome purchasing habits). Difficulty is identified as a barrier in Hoe17, Hun16, Kem20, Mak14 and Poh15. Hoe17, Hun16 and Urb20 advocate for small behavioural shifts, therefore assumptions are made about small behavioural shifts overcoming the 'difficulty' barrier. Whereas Kem20, Mak14 and Poh15 identify other strategies for overcoming difficulty, such as increasing product availability (Poh15) and targeting food preparation skills to increase vegetarianism (Kem20).

Other examples of the discrepancy between barriers identified and subsequent policy recommendations include how health messages are only advocated strongly in one study (Hoe17), whereas health was identified as a barrier (as part of psychological distance) in Hoe17, Kem20, Poh15, and Urb20. Notable is the lack of policy recommendations that address the emotional elements of behaviour or barriers to behaviour change, i.e. meat attachment or enjoyment (Kem20; Poh15).

Study	Study outcomes (barriers) **(Remaining barriers)**	Policy recommendations
Cir19	Moral and ethical reasons Meat attachment Social norms	Focus on drivers and address barriers
Hoe17	Health Cultural norms Happy with current behaviour **Attitude to reducing meat consumption vs increasing plant-based diet** **Low knowledge on environmental impact** **Habit** **Difficulty**	Health messages Framing – multiple targeted approach Social norms and emotion Smaller behavioural shifts
Hun16	'Threat other' vs 'threat close' Understanding of severity and vulnerability of climate change is significant Understanding of climate impact **Self-efficacy and response efficacy** **Difficulty**	Emphasize threat to others Increase knowledge of climate impact Start with smaller behaviour changes Non-climate framing
Kem20	Knowledge of environmental impact Difficulty Lack of trust in supply chains Enjoyment of meat **Cultural heritage** **Childhood associations** **Health**	Increase information and skills Target campaigns by life stage/stage of meat reduction journey

Mak14	Knowledge **Habit** **Difficulty**	Increase knowledge of climate impacts Increase availability (context and habit) Focus on food waste
Poh15	Health Masculinity, traditionalism and hierarchies **Difficulty** **Enjoyment** **Existing behaviour**	Consider policy across issues Focus on different value/norm groups Focus on already 'sympathetic' groups
Urb20	Subjective norms Others' beliefs Knowledge of nutrition **Habit** **Self-efficacy**	Use Social Judgement Theory Implement small steps Improve nutritional literacy

Table 7 Barriers, policy recommendations, and remaining barriers not addressed through policy recommendations, per study.

5.4 Discussion

This discussion focuses on overcoming the barriers identified and discusses the application of this research to policy, practice and research going forward.

5.4.1 Kollmuss and Agyeman (K&A)

Through applying the Kollmuss and Agyeman (2002) model to analysis, habits were found to be the most significant barrier to change. This is supported by literature which explores habit and broader pro-environmental behaviour change (Verplanken and Roy, 2016), although Çoker and van der Linden (Çoker and van der Linden, 2020) identified past behaviour, not habits, as a significant factor in predicting behaviour. Habitual behaviour differs from past behaviour as habit relies on the automatic behavioural system (Tyers, 2018), and only changes when external forcing factors change (Steg and Vlek, 2009), therefore this should be considered when designing interventions. Habits are much less frequently researched in the pro-environmental behaviour sphere (Russell et al., 2017), potentially due to the challenges with longitudinal research and self-reported studies. This suggests that difficulties in researching habit can have knock-on effects for policymakers when designing interventions.

Values and attitudes are commonly identified as barriers, and are found to relate to and affect other barriers (such as emotional attachment to meat and cultural norms). This potentially indicates values and attitudes as moderating variables, which could be an area for future research. Emotional barriers were prominent, with enjoyment being frequently highlighted. Loughnan *et al*. (Loughnan et al., 2014) found negative emotions associated with eating meat were subconsciously discarded, which could indicate that automatic behavioural processes associated with habit are also involved in the emotional elements of meat-eating behaviour. Knowledge is frequently identified as a barrier to change but is heavily tied to emotion and values, for example manifesting as disbelief. This highlights the interrelationships between barriers and supports the overall framework of the Kollmuss and Agyeman (2002) model, which portrays a dynamic and multifaceted behaviour change process.

There was widespread overlap between the barriers; and the interrelationships indicates a need to construct interventions which address multiple barriers by considering barriers holistically, as an interrelated whole (Pohjolainen et al., 2015), and reduce the risk of the rebound effect or negative spillover (Capstick et al., 2019).

5.4.2 Psychological distance

When the remaining barriers were explored through the lens of psychological distance, these gaps in categorisation of barriers are filled. There are certain overlaps with some barriers found in Kollmuss and Agyeman (2002), e.g. disbelief in climate (psychological distance) and emotion, or threat of climate change (psychological distance) and values.

Difficulty and health were the dominant barriers within the concept of psychological distance. The 'difficulty' barrier encompassed; the perceived lack of nutritional literacy which would be required to move to a more plant-based diet, contextual factors such as availability, as well as the gap between the perception of these barriers and the actual barriers. This broad range of 'difficulties' identified suggests that a one-size-fits-all intervention approach would be ineffective to overcome these multi–dimensional barriers.

Health was found to be both a barrier and a driver to reducing meat consumption. The distances identified here were often contradictory - beliefs around the '4N's' of meat – that meat is "natural, normal, necessary, and nice" (55, p.114), and the health benefits of eating a plant-based diet. Cognitive dissonance such as this has been identified as the 'meat paradox'; where an individual values both animal rights and eating meat (Loughnan et al., 2014), which supports a moral disconnect between animal and self (Graça et al., 2014), further exemplifying a manifestation of psychological distance. This cognitive dissonance was identified as the most significant factor in Stoll-Kleemann and Schmidt's (Stoll-Kleemann and Schmidt, 2017) review of factors which influence meat consumption in developed and transition countries. The idea of a disconnect between beliefs around health and the environment that are not evidence based, has been repeatedly identified (Leire and Thidell, 2005; Stubbs et al., 2018).

Social 'barriers' could be targeted to bridge psychological distance or indicate a psychological proximity. Evidence showing that threat 'close' is less effective than threat 'other' could help with framing an intervention, for example framing messaging around impacts on others or social norms. The idea of proximity does not align simply with existing work indicating that distance needs to be bridged for a behavioural shift to occur (Spence et al., 2012). This supports McDonald *et al.*'s (McDonald et al., 2015) findings around 'can climate change get too close?' and calls for a nuanced understanding of bridging distance and facilitating proximity (Loy and Spence, 2020).

Categorising most of the barriers (which cannot be explained through Kollmuss and Agyeman (2002)) as uncertainty and social distance, and therefore this

provides an opportunity for interventions to overcome them. Social elements of psychological distance could be argued to be discreet and potentially easier to design interventions to be overcome (health behaviour campaigns; communication of threat etc.). Uncertainty presents nebulous, value-based concepts such as disbelief, trust and familiarity, which could be harder to overcome.

5.4.3 Commonalities and outliers across barriers

The exploration of psychological barriers through the two models highlights the inter-relationships between barriers. The outliers - barriers which didn't fit into either categorisation – can offer further insight. All three outliers manifest as gaps in an individual's behavioural process. These gaps occurred 1) between behavioural determinants, 2) between barriers themselves, and 3) between the perceptions of barriers and actual barriers. The theme of perception repeatedly emerged, and this is mirrored across general pro-environmental behaviour change literature. Gaps were identified between individual's perception of their own knowledge, skills, self-efficacy, and difficulty, which relates to themes of denial (Gifford, 2011), and affect barriers in both Kollmuss and Agyeman (2002) and psychological distance.

It could be argued that values, knowledge, emotion and habit can manifest as direct blocks on behaviour change (as displayed in Kollmuss and Agyeman (2002)). Exploring barriers through the lens of psychological distance suggests that distances (or gaps) can manifest to prevent behaviour change. However, the integration, overlaps, and outliers to these models, show that gaps within the behavioural process can happen in many ways beyond the distances identified within psychological distance. The prominence of the issue of perception indicates a manifestation of psychological distance within the behavioural process itself, in addition to the existing understanding of psychological distance which relates the self to the external (Trope and Liberman, 2010b). Understanding barriers in a more holistic and integrated sense can enable policymakers and other stakeholders to design interventions that are more effective, by targeting multiple barriers and preventing inadvertent activation of a barrier through mismanagement of another.

5.4.4 Overcoming psychological barriers

Lessons can be drawn from the policy recommendations within these studies. Framing and messaging was the most frequently recommended intervention,

which aligns with the wider literature (Graham and Abrahamse, 2017; Vainio et al., 2018; Palomo-Vélez et al., 2018; Stea and Pickering, 2019). Tailoring messaging to different value groups could also complement messaging around co-benefits (Sanchez-Sabate and Sabaté, 2019). The difference in attitudes and emotions associated with reducing meat consumption versus increasing plant-based diet/meat substitutes is a clear indication for how framing and messaging need to be built around values, attitudes, social norms (social psychological distance) and emotion (MacDiarmid, 2013). Findings around proximity within social psychological distance, especially in the context of health, supports existing research that highlights health as an effective framing and messaging strategy (Stubbs et al., 2018; Sanchez-Sabate et al., 2019). Findings around co-benefits indicate that if interventions are aligned with related policy areas (i.e. climate and public health policy), opportunities for positive spillover could occur (Truelove et al., 2014; Lanzini and Thøgersen, 2014).

Increasing knowledge around the impacts of climate change and relating that to individual meat consumption could potentially be achieved through informational policies and campaigns. However, the effectiveness of this alone has been widely questioned (Gifford, 2011). Policy focused on overcoming the 'knowledge' barrier only addresses one element of a holistic process (and knowledge was found to be a relatively weak barrier). Instead of applying informational policies to overcome the direct knowledge barrier, focusing on the knowledge manifestation within psychological distance (i.e. difficulty, self-efficacy) could prove more effective through targeting the gaps in the process.

Nudge Theory was frequently implicitly recommended for policy, often in conjunction with another strategy such as informational campaigns. Applying nudge theory to overcome the initial barriers associated with a behaviour being 'too big to change', could be effective in some contexts. However, barriers are interrelated and multifaceted. Nudge Theory taps in to the automatic system of behaviour (Oliver, 2013; Tyers, 2018), which aligns with psychological distance and behavioural gaps, as the unconscious system drives embedded behaviour which could block change. This merits further research into this mechanism and explorations around why Nudge Theory is so readily advocated. Possible explanations could lie in the existing paradigms in environmental policymaking, i.e. the focus on small, 'achievable' steps advocated by nudge theory, and the reluctance of traditional behavioural economics to advocate for more ambitious interventions.

The themes which emerge in the policy recommendations of the papers reviewed do not focus on the dominant barriers identified within the research, and many barriers are not addressed at all within the policy recommendations.

Habit and existing behavioural patterns are formulated from a complex array of determinants, and this should be more clearly recognised within policy recommendations, as identifying strategies to overcome one element of a barrier does not consider barriers as a holistic construct.

The disparity between the policy recommendations and the barriers identified could indicate a reliance on research that focuses on encouraging behavioural determinants (as opposed to addressing psychological barriers). It could also indicate a process gap within research (basing policy recommendations on traditional/existing policy strategies, as opposed to being led by the findings), or potentially a reluctance to advocate for policy which might be seen as unappealing to policymakers. The complexity of the barriers identified, especially regarding barriers manifesting as gaps, indicates difficulty in creating policy recommendations, or other interventions to overcome barriers.

5.4.5 Policy recommendations

The following are identified as policy recommendations:

1. Existing habits are the most significant barrier to change. Interventions should target repeated behaviours.
2. Messaging and framing of communications should be tailored to individuals/groups underlying values; and these need to be better understood.
3. The relationship between health and reducing meat consumption for environmental and climate reasons could be utilised to align with individual values.
4. Incremental interventions that are buildable could be appropriate. The assumptions that underlie these recommendations should be explored.
5. The potential for co-benefits across other high impact pro-environmental behaviours (i.e. consumption patterns more broadly) and other social issues (i.e. health) is high. Crosscutting policy is required to achieve this, to avoid rebound effects or inadvertent repercussions.
6. Barriers should be considered holistically to increase effectiveness of interventions and reduce risk of activation of direct or indirect barriers.

These policy recommendations were developed into a policy brief for DEFRA.

The policy recommendations for overcoming psychological barriers should be read in conjunction with literature on external and contextual barriers, as

reductions in meat consumption cannot be achieved by overcoming psychological barriers to change alone.

5.4.6 Theoretical integration

The integration of the Kollmuss and Agyeman (2002) model and psychological distance provides a more comprehensive analytical framework and a critique of the theories. Both captured and categorised barriers identified within the research body, and complemented the other, which increased the comprehensiveness of the framework for analysis. A more formal development of the Kollmuss and Agyeman (2002) model to include components of psychological distance would be an interesting avenue for future research. There were several barriers which could not be categorised within either the Kollmuss and Agyeman (2002) framework or psychological distance. This indicates that although combining the two frameworks does provide a useful analytical framework, gaps in the behavioural process were difficult to categorise. Theoretical integration such as this, is advocated repeatedly across pro-environmental behaviour change literature (Kennedy and Bishop, 2008; Klöckner and Blöbaum, 2010; Zur and Klöckner, 2014) in order to ensure usefulness to policymakers. Enhanced interdisciplinarity across the sustainability-health divide could help to integrate theory more effectively.

5.4.7 Limitations

This study was structured through a rapid evidence review methodology, which ensured rigour and transparency in the literature gathering and analysis. Only seven studies were included in the analysis due to the small number of experimental studies exploring barriers explicitly, and the specific focus on psychological barriers (as opposed to contextual barriers). There are several reviews on meat consumption reductions that are highly cited and are of a similar scale, indicating the value and interest in a small-scale review such as this (Bianchi, Garnett, et al., 2018; Bianchi, Dorsel, et al., 2018; Sanchez-Sabate et al., 2019). Variation in research design makes quantitative claims about significance of variables and barriers difficult, so only general trends can be described. Nevertheless, the thematic structure of the review enables comparisons to be made across study outcomes. Conducting a rapid review has resulted in a potentially narrow conceptualisation of psychological barriers, which runs the risk of excluding different disciplinary understandings.

5.5 Conclusions

This rapid evidence review found that habit was the most significant barrier to reducing meat consumption, which aligns neatly with the Kollmuss and Agyeman (2002) (Kollmuss and Agyeman (2002)) model. Values and attitudes were frequently found to be moderators or co-variates of other barriers. Some barriers did not fit into the Kollmuss and Agyeman (2002) model, such as difficulty and self-efficacy, and these remaining study outcomes were categorised within psychological distance. ‘Uncertainty’ and ‘social distance’ categories captured many of the remaining barriers, with difficulty and health being most frequently identified. However, there were also several barriers which did not fit into either Kollmuss and Agyeman (2002) or psychological distance. These outliers could all be argued to commonly manifest as a gap between determinants and barriers, or between barriers and barriers, or finally, between self-perception of barriers and actual barriers. These findings provide an application and critique of how behavioural theory can be used to analyse research and interventions. The psychological barriers identified should be considered holistically and directly inform policies and practice, to encourage a reduction in meat consumption and overcome the barriers preventing change. Only through identifying the barriers and understanding the underlying mechanisms, can the most effective interventions be created. Further research is needed into conceptualising barriers as gaps across environmental psychology and related disciplines, as the current focus is dominated by behavioural determinants as barriers, instead of barriers in their own right. The question of a disparity between the study outcomes and policy recommendations raises interesting questions. It potentially reflects a lack of critique of the assumptions that researchers work within when considering policy recommendations. A broader, more creative approach to policy recommendations that are not limited to existing dominant policy paradigms, would be a welcome approach to future research.

5.6 References

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes. 50(2), pp.179–211.

Bianchi, F., Dorsel, C., Garnett, E., Aveyard, P. and Jebb, S.A. 2018. Interventions targeting conscious determinants of human behaviour to reduce the demand for meat: a systematic review with qualitative comparative analysis. International Journal of Behavioral Nutrition and Physical Activity. 15.

Bianchi, F., Garnett, E., Dorsel, C., Aveyard, P. and Jebb, S.A. 2018. Restructuring physical micro-environments to reduce the demand for meat: a systematic review and qualitative comparative analysis. The Lancet Planetary Health. 2(9), pp.e384–e397.

Brunelle, T., Coat, M. and Viguié, V. 2017. Demand-side mitigation options of the agricultural sector: Potential, barriers and ways forward. OCL - Oilseeds and fats, Crops and Lipids. 24(1).

Capstick, S., Whitmarsh, L.E., Nash, N.C., Haggar, P. and Lord, J. 2019. Compensatory and catalysing behavioural beliefs: Development and psychometric properties of an instrument for measuring spillover-related perceptions in seven countries. Frontiers in Psychology. 10.

Circus, V.E. and Robison, R. 2019. Exploring perceptions of sustainable proteins and meat attachment. British Food Journal. 121(2), pp.533–545.

Clonan, A., Wilson, P., Swift, J.A., Leibovici, D.G. and Holdsworth, M. 2015. Red and processed meat consumption and purchasing behaviours and attitudes: impacts for human health, animal welfare and environmental sustainability. Public Health Nutrition. 18(13), pp.2446–2456.

Çoker, E.N. and van der Linden, S. 2020. Fleshing out the theory of planned of behavior: Meat consumption as an environmentally significant behavior. Current Psychology.

Dietz, T., Gardner, G.T., Gilligan, J., Stern, P.C. and Vandenbergh, M.P. 2009. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. Proceedings of the National Academy of Sciences. 106(44), pp.18452–18456.

Gifford, R. 2006. A general model of social dilemmas. International Journal of Ecological Economics & Statistics. 4(S06).

Gifford, R. 2011. The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. American Psychologist. 66(4), pp.290–302.

Gifford, R.D. and Chen, A.K.S. 2017. Why aren't we taking action? Psychological barriers to climate-positive food choices. Climatic Change. 140(2), pp.165–178.

Girod, B., van Vuuren, D.P. and Hertwich, E.G. 2014. Climate policy through changing consumption choices: Options and obstacles for reducing greenhouse gas emissions. Global Environmental Change. 25, pp.5–15.

Grabs, J. 2015. The rebound effects of switching to vegetarianism. A microeconomic analysis of Swedish consumption behavior. Ecological Economics. 116, pp.270–279.

Graça, J., Calheiros, M.M. and Oliveira, A. 2014. Moral Disengagement in Harmful but Cherished Food Practices? An Exploration into the Case of Meat. Journal of Agricultural and Environmental Ethics. 27(5), pp.749–765.

Graça, J., Godinho, C.A. and Truninger, M. 2019. Reducing meat consumption and following plant-based diets: Current evidence and future directions to inform integrated transitions. Trends in Food Science & Technology. 91, pp.380–390.

Graham, T. and Abrahamse, W. 2017. Communicating the climate impacts of meat consumption: The effect of values and message framing. Global Environmental Change-Human and Policy Dimensions. 44, pp.98–108.

Grimmer, M. and Miles, M.P. 2017. With the best of intentions: a large sample test of the intention-behaviour gap in pro-environmental consumer behaviour. International Journal of Consumer Studies. 41(1), pp.2–10.

Hoek, A.C., Pearson, D., James, S.W., Lawrence, M.A. and Friel, S. 2017. Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours. Appetite. 108, pp.117–131.

Hunter, E. and Roos, E. 2016. Fear of climate change consequences and predictors of intentions to alter meat consumption. FOOD POLICY. 62, pp.151–160.

Kemper, J.A. 2020. Motivations, barriers, and strategies for meat reduction at different family lifecycle stages. Appetite. 150.

Kennedy, L. and Bishop, I.D. 2008. Land Use Decision Making in a Virtual Environment In: C. Pettit, W. Cartwright, I. Bishop, K. Lowell, D. Pullar and D. Duncan, eds. Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning [Online]. Berlin, Heidelberg: Springer Berlin Heidelberg, pp.591–608. Available from: https://doi.org/10.1007/978-3-540-69168-6_29.

Klöckner, C.A. 2013. A comprehensive model of the psychology of environmental behaviour—A meta-analysis. Global Environmental Change. 23(5), pp.1028–1038.

Klöckner, C.A. and Blöbaum, A. 2010. A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. Journal of Environmental Psychology. 30(4), pp.574–586.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research. 8(3), pp.239–260.

Lacroix, K., Gifford, R. and Chen, A. 2019. Developing and validating the Dragons of Inaction Psychological Barriers (DIPB) scale. Journal of Environmental Psychology. 63, pp.9–18.

Lanzini, P. and Thøgersen, J. 2014. Behavioural spillover in the environmental domain: An intervention study. Journal of Environmental Psychology. 40, pp.381–390.

Lea, E.J., Crawford, D. and Worsley, A. 2006. Public views of the benefits and barriers to the consumption of a plant-based diet. European Journal of Clinical Nutrition. 60(7), pp.828–837.

Leire, C. and Thidell, Å. 2005. Product-related environmental information to guide consumer purchases – a review and analysis of research on perceptions,

understanding and use among Nordic consumers. Journal of Cleaner Production. 13(10–11), pp.1061–1070.

Leiserowitz, A.A. 2005. American Risk Perceptions: Is Climate Change Dangerous?: American Risk Perceptions. Risk Analysis. 25(6), pp.1433–1442.

Lentz, G., Connelly, S., Mirosa, M. and Jowett, T. 2018. Gauging attitudes and behaviours: Meat consumption and potential reduction. Appetite. 127, pp.230–241.

Lorenz, B.A. and Langen, N. 2018. Determinants of how individuals choose, eat and waste: Providing common ground to enhance sustainable food consumption out-of-home. International Journal of Consumer Studies. 42(1), pp.35–75.

Loughnan, S., Bastian, B. and Haslam, N. 2014. The Psychology of Eating Animals. Current Directions in Psychological Science. 23(2), pp.104–108.

Loy, L.S. and Spence, A. 2020. Reducing, and bridging, the psychological distance of climate change. Journal of Environmental Psychology. 67, p.101388.

MacDiarmid, J.I. 2013. Is a healthy diet an environmentally sustainable diet? Proceedings of the Nutrition Society. 72(1), pp.13–20.

Makiniemi, J.-P. and Vainio, A. 2014. Barriers to climate-friendly food choices among young adults in Finland. Appetite. 74, pp.12–19.

McDonald, R.I., Chai, H.Y. and Newell, B.R. 2015. Personal experience and the ‘psychological distance’ of climate change: An integrative review. Journal of Environmental Psychology. 44, pp.109–118.

McKenzie-Mohr, D. 2000. New Ways to Promote Proenvironmental Behavior: Promoting Sustainable Behavior: An Introduction to Community-Based Social Marketing. Journal of Social Issues. 56(3), pp.543–554.

Oliver, A. 2013. From Nudging to Budging: Using Behavioural Economics to Inform Public Sector Policy. Journal of Social Policy. 42(4), pp.685–700.

Palomo-Vélez, G., Tybur, J.M. and van Vugt, M. 2018. Unsustainable, unhealthy, or disgusting? Comparing different persuasive messages against meat consumption. Journal of Environmental Psychology. 58, pp.63–71.

Payne, P. 2002. Post-metatheorizing Environmental Behaviours in Environmental Education. Environmental Education Research. 8(3), pp.307–314.

Piazza, J., Ruby, M.B., Loughnan, S., Luong, M., Kulik, J., Watkins, H.M. and Seigerman, M. 2015. Rationalizing meat consumption. The 4Ns. Appetite. 91, pp.114–128.

Pohjolainen, P., Vinnari, M. and Jokinen, P. 2015. Consumers' perceived barriers to following a plant-based diet. British Food Journal. 117(3), pp.1150–1167.

Poortinga, W., Steg, L. and Vlek, C. 2004. Values, Environmental Concern, and Environmental Behavior: A Study into Household Energy Use. Environment and Behavior. 36(1), pp.70–93.

Rees, R., Oliver, K., Woodman, J. and Thomas, J. 2009. Children's views about obesity, body size, shape and weight: a systematic review. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Ritchie, H. 2017. 'Meat and Dairy Production'. Published online at OurWorldInData.org. Retrieved from: "https://ourworldindata.org/meat-production" [Online Resource].

Rogers, R.W. 1975. A Protection Motivation Theory of Fear Appeals and Attitude Change1. The Journal of Psychology. 91(1), pp.93–114.

Russell, S.V., Young, C.W., Unsworth, K.L. and Robinson, C. 2017. Bringing habits and emotions into food waste behaviour. Resources, Conservation and Recycling. 125, pp.107–114.

Sanchez-Sabate, R., Badilla-Briones, Y. and Sabate, J. 2019. Understanding Attitudes towards Reducing Meat Consumption for Environmental Reasons. A Qualitative Synthesis Review. SUSTAINABILITY. 11(22).

Sanchez-Sabate, R. and Sabaté, J. 2019. Consumer attitudes towards environmental concerns of meat consumption: A systematic review. International Journal of Environmental Research and Public Health. 16(7).

Singh, A.S., Zwickle, A., Bruskotter, J.T. and Wilson, R. 2017. The perceived psychological distance of climate change impacts and its influence on support for adaptation policy. Environmental Science & Policy. 73, pp.93–99.

Spence, A., Poortinga, W. and Pidgeon, N. 2012. The Psychological Distance of Climate Change. Risk Analysis. 32(6), pp.957–972.

Stea, S. and Pickering, G.J. 2019. Optimizing Messaging to Reduce Red Meat Consumption. Environmental Communication. 13(5), pp.633–648.

Steg, L. and Vlek, C. 2009. Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology. 29(3), pp.309–317.

Steinfeld, H., Gerber, P., Wassenaar, T.D., Castel, V., Rosales, M., Rosales, M. and de Haan, C. 2006. Livestock's long shadow: environmental issues and options. Food & Agriculture Org.

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A. and Kalof, L. 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review. 6(2), p.17.

Stevens, T. 2017. The influence of environmental awareness on inducing lower carbon dietary change in the UK. Meliora: International Journal of Student Sustainability Research. 1(1).

Stoll-Kleemann, S. and Schmidt, U.J. 2017. Reducing meat consumption in developed and transition countries to counter climate change and biodiversity loss: a review of influence factors. Regional Environmental Change. 17(5), pp.1261–1277.

Stubbs, R.J., Scott, S.E. and Duarte, C. 2018. Responding to food, environment and health challenges by changing meat consumption behaviours in consumers. Nutrition Bulletin. 43(2), pp.125–134.

Taufik, D., Verain, M.C.D., Bouwman, E.P. and Reinders, M.J. 2019. Determinants of real-life behavioural interventions to stimulate more plant-based and less animal-based diets: A systematic review. Trends in Food Science & Technology. 93, pp.281–303.

Trope, Y. and Liberman, N. 2010a. Construal-Level Theory of Psychological Distance. Psychological review. 117(2), pp.440–463.

Trope, Y. and Liberman, N. 2010b. Construal-Level Theory of Psychological Distance. Psychological review. 117(2), pp.440–463.

Truelove, H.B., Carrico, A.R., Weber, E.U., Raimi, K.T. and Vandenbergh, M.P. 2014. Positive and negative spillover of pro-environmental behavior: An integrative review and theoretical framework. Global Environmental Change. 29, pp.127–138.

Tyers, R. 2018. Nudging the jetset to offset: voluntary carbon offsetting and the limits to nudging. Journal of Sustainable Tourism. 26(10), pp.1668–1686.

Urbanovich, T. and Bevan, J.L. 2020. Promoting Environmental Behaviors: Applying the Health Belief Model to Diet Change. Environmental Communication. 0(0), pp.1–15.

Vainio, A., Irz, X. and Hartikainen, H. 2018. How effective are messages and their characteristics in changing behavioural intentions to substitute plant-based foods for red meat? The mediating role of prior beliefs. Appetite. 125, pp.217–224.

Vermeulen, S.J., Campbell, B.M. and Ingram, J.S.I. 2012. Climate Change and Food Systems. Annual Review of Environment and Resources. 37(1), pp.195–222.

Verplanken, B. and Roy, D. 2016. Empowering interventions to promote sustainable lifestyles: Testing the habit discontinuity hypothesis in a field experiment. Journal of Environmental Psychology. 45, pp.127–134.

Wynes, S., Nicholas, K.A., Zhao, J. and Donner, S.D. 2018. Measuring what works: quantifying greenhouse gas emission reductions of behavioural interventions to reduce driving, meat consumption, and household energy use. Environmental Research Letters. 13(11), p.113002.

Zur, I. and Klöckner, C.A. 2014. Individual motivations for limiting meat consumption. British Food Journal. 116(4), pp.629–642.

5.7 Bridging discussion

This chapter focussed in on one specific high impact behaviour – meat consumption, and the associated behavioural process surrounding this highly complex and often value and emotion-based decision and habit. Focusing on meat consumption enabled a deep dive into the mechanics of the psychological barriers preventing potential behavioural shift to a lower carbon and lower environmental impact behaviours. Meat consumption was chosen due to the ubiquity of food consumption behaviours across all groups in society (i.e. everyone engages in food consumption behaviours, but not everyone engages in high-carbon transportation behaviours). I found that the research body encountered similar gaps and limitations to those found in the systematic review, where experimental studies on pro-environmental behaviour is limited in temporal scope and participant variation. Therefore, the next phase of the research addressed these gaps by conducting a longitudinal piece of research across a more demographically diverse population (compared to the reliance on university populations across much of the research). This chapter explored integrating psychological distance into the Kollmuss and Agyeman (2002) model of pro-environmental behaviour, which was utilised and further explored within the experimental methodology is used in the following chapter, in order to build empirical findings on this theoretical discussion. The narrow body of work which focuses on psychological barriers to meat consumption behaviours was expanded through an experimental design which investigates the impact of an intervention on meat consumption intention and self-reported behaviour. The content for the intervention was chosen to have clear links to meat consumption (through environmental themes such as land use, deforestation, animal welfare and ethical considerations), in order to encourage participants to make a direct connection between the intervention and the questions around their own meat consumption behaviours. This chapter also discussed how the policy recommendations found in the included studies were all structured within existing dominant policy paradigms (e.g. nudge). Therefore, the following chapter will endeavour to broaden the policy recommendations to include catalytic intervention recommendations and to be creative and ambitious with policy and research recommendations.

Chapter 6 The effect of an environmental virtual reality experience on pro-environmental behaviour

6.1 Introduction

Individual behaviour change has huge emissions-reducing potential, both directly through actions such as reducing meat consumption and reducing private car use, as well as indirectly through purchasing power and encouraging political will. Pro-environmental behavioural outcomes can be achieved with or without conscious choice or effort. Often these behavioural changes are at no cost (or cost saving) to individuals and households (Creutzig et al., 2016), and have positive co-benefits such as improved health and wellbeing, however, there can be significant structural and psychological barriers to change. Structural barriers include policy, infrastructures and regulations which limit individual choice, market forces which prevent and disincentivise change, and other economic and social barriers which reduce an individual's ability to make pro-environmental choices. Psychological barriers include an individual's perception of self-efficacy and agency, the values, attitudes and emotional connection to issues, as well as their pre-existing behavioural and habitual patterns. Through behavioural changes, an average individual in the UK could reduce their carbon emissions significantly. High-impact behavioural changes include reducing meat consumption (up to 22% carbon saving (Lacroix, 2018)), living car free (26-76% carbon saving (Chester et al., 2013)), taking one fewer flights per year (700-2800 kgCO2e carbon saving, (Wynes and Nicholas, 2017)); all of which could collectively create a huge positive change. Despite this, political will to support and facilitate behavioural changes through policy has been low, therefore onus on encouraging behaviour change largely falls to other stakeholders including NGOs and campaigning organisations.

A key part of encouraging and facilitating behaviour change is communication, as it can play a crucial role in shifting social expectations and societal norms. Effective communication of policy, risk, science, and individual and collective responsibility is necessary in order to ensure there is sufficient public buy-in and shifting of social norms. Bringing experiences of the impacts of climate change and experiencing environmental issues as close to first hand as is possible, could increase the personal relevance and resonance necessary to encourage individual action on climate change and promote environmental behaviour change (O'Neill and Nicholson-Cole, 2009). Virtual reality (VR) is an exciting (relatively) new tool for environmental communication, which could facilitate this

(Fauville et al., 2020). We need to understand how VR affects pro-environmental behaviour across a range of behavioural determinants and outcomes, in order to explore its effectiveness more thoroughly. This is examined in this chapter through exploring the research question “Can psychological barriers to pro-environmental behaviour change be overcome through VR?”.

6.1.1 Virtual reality as a tool for communicating climate change

VR is increasingly used as a communication tool by organisations across a range of sectors including charities, medicine, education and architecture/planning. Organisations such as the UN, World Bank, Oxfam and Conservation International have all invested in creating communications and campaigns in virtual reality (VR) to further their message. VR can transport individuals to new or different times, places and experiences, which individuals may otherwise never be able to experience.

Environmentally themed VR communications often centre on experiencing nature or wilderness. These are often ‘distant’ experiences where VR is assumed to ‘bridge the gap’ between the individual and distant places and people (Buljat, 2022) (for example: the Arctic (‘Arctic 360°’ - Guardian VR), small island states (‘Our Home, Our People’ - World Bank) and the Amazon rainforest (‘Guardians of the forest’ - UNVR)). The organisations investing in VR communications can be assumed to be creating these with a purpose in mind (e.g. increasing awareness, donations, changing behaviour). The assumptions that these experiences reduce the perceived distance and increase the connection felt between the individual and other people/places/experiences are beginning to be explored.

Chapter 3 found through a systematic review that the research around measuring pro-environmental outcomes after using virtual reality is dominated by questions on the impact of environment-focussed VR on emotion, knowledge, awareness and connection to nature, with less evidence supporting the assumptions about increasing empathy, knowledge or awareness translating into pro-environmental behaviour change (especially over the long term). Research has found that VR can create emotional responses such as empathy, which was found to increase alongside pro-social behaviour following a VR experience (Breves, 2020), and also increase pro-environmental attitudes compared to a non-empathetic experience (Fonseca and Kraus, 2016). However, there are mixed results depending on the specific element of emotional response, as Calogiuri et al. (2018) found that affect and enjoyment

was lower in a virtual environment than in a guided nature walk. Research has also found that VR can increase awareness of environmental issues such as the climate impacts on coral reefs (Breves and Heber, 2020), plastic pollution (Chirico et al., 2020) and the interactions of water pollution, climate change and habitat damage (Bennett and Canner, 2019). The current research on the effects of VR on climate change awareness is well presented in Fauville et al. (2020). Environmental knowledge has been found to increase in certain situations; for instance a diving experience increased knowledge of ocean acidification (Markowitz et al., 2018), and a vivid and personally relevant VR experience increased students' cognition of their own water consumption by 54% (Hsu et al., 2018). Connection to nature has been shown to increase through immersive virtual nature experiences (Breves and Heber, 2020), and Soliman et al. (2017) found that virtual nature experiences resulted in a higher connection to nature than built environment experiences. Relationships have been found between higher Connection to Nature (CNS) and pro-environmental behaviour (Whitburn et al., 2019), as well as positive outcomes in terms of wellbeing and behaviour (Coughlan et al., 2022).

This research body has grown rapidly over the last 20 years, however the translation of the effect of increased awareness, knowledge and empathy on subsequent pro-environmental behaviour is unclear. Existing research on the pro-environmental behavioural effects of VR is focused on small scale, low impact behaviours such as hot water use (Bailey et al., 2015) and the use of paper napkins to mop up spilled water (Ahn et al., 2014). This research is valuable in measuring real behaviour (as opposed to self-reported), and the focus on small-scale behaviours is understandable due to the logistical difficulties in observing real behaviour, however, there is need for more research (both directly measured and self-reported) on high impact behaviours. This chapter builds on previous experimental work on determinants of behaviour, by examining the common underlying assumptions around VR use for behavioural change, and primarily, its ability to bridge psychological distance.

6.1.2 VR and psychological distance

Psychological distance is the concept that the cognitive distance felt between the individual and places, people or issues can limit action on those issues (Jones et al., 2017) and is a theory based on the Construal Level Theory (Trope and Liberman, 2010). This distance can manifest in four different (but often interrelated ways); social, spatial, temporal, and uncertainty (Spence et al.,

2012), and having a lower psychological distance has been associated with higher concern and behavioural intention (Spence et al., 2012). Research has shown that VR can reduce the psychological distance of ocean acidification, with 62% of participants feeling psychological closeness with ocean acidification following a VR intervention in Raja and Carrico's (2021) study. There may be contextual limitations on the potential of VR to bridge various components of psychological distance, as Breves and Schramm (2021) found that although higher immersiveness simulated more direct experiences, higher immersiveness of issues already perceived to be 'close' could prove to be counter-productive. Despite this work, psychological distance is under-researched in terms of pro-environmental behaviour generally, as well as in the context of the use of VR to impact pro-environmental behaviour. There are big opportunities to expand the research on psychological distance through the use of VR, in order to test the implicit assumptions that VR can bring distant experiences closer to the individual, and how that mechanism might manifest.

6.1.3 The current study; aims and research questions

This chapter examines the effect of a VR 360° environmental documentary film on a range of behavioural determinants and the interplay with psychological distance (as a barrier to change), to further understand potential behavioural mechanisms at play when using VR for pro-environmental communications. This chapter asks the following questions:

> RQ7: What are the effects of an environmental VR intervention over time on behavioural determinants and outcomes?
>
> RQ8: What are the effects of an environmental VR intervention on psychological distance?

This study applies the Kollmuss and Agyeman (2002) (K&A) model of pro-environmental behaviour, due to its holistic consideration of behavioural determinants and explicit categorisation and placement of psychological barriers. A range of behaviours are explored, with meat consumption examined in detail, due to the topic focus of the VR film. Additionally, psychological distance is explored as a component of psychological barriers in the Kollmuss and Agyeman (2002) model, in order to examine the implicit assumptions often present in VR communications that VR can bring distant experiences closer to the individual. The centralisation of a holistic understanding of behaviour in the conceptual framework of this research manifests through the range of behavioural determinants measured, but also through the use of the Recurring

Pro-environmental Behaviour Scale (REBS) which includes a range of everyday household behaviours. This crucially includes some high impact behaviours such as flying, transport use and meat consumption.

Section 6.2 outlines the experimental design, measures and analysis used, Section 6.3 summarises the findings, and Section 6.4 situates the findings in the context of existing work and suggests future research directions.

6.2 Methods

An experimental design was used to examine these research questions due to the need to examine multiple behavioural factors and the added rigour provided by the use of a control group. As a large proportion of the existing research in this area utilises experimental designs, this enables buildable findings due to the use of externally validated metrics. This experimental design was composed of a pre-post test design where participants completed surveys before and after exposure to a VR experience (or no intervention, as with the control group), with a repeat measure 3 weeks later. The survey included quantitative metrics exploring a range of behavioural factors, and qualitative questions around the perception of, and response to, the VR experience. Full details of the experimental design can be found in Chapter 3: Methods.

6.2.1 Intervention

The VR film (This is Climate Change: Feast) was an ~8-minute documentary film set in the Amazon and begins by descending into the rainforest and seeing two men cutting down a tree, surrounded by some charismatic megafauna. The next scene explores a huge clearing of felled trees and the machinery being operated to transport the logs, then moving to showing an aerial view of the extent of the deforestation. The film then moves to seeing cattle farms in the arid environment, surrounded by rainforest in the distance. The viewer is then placed in the cattle field while the herd moves past and around the camera. The next scene hovers above the cattle as they are forced into the abattoir, and then follows the workers inside with the meat hanging. There are many interrelated environmental and ethical issues addressed within this film, and it knits together issues of land use, deforestation, desertification, social implications through the people shown to be dependent on this industry for employment, mass meat consumption and ethical issues around animal welfare in an emotive way, in an

'exotic', distant setting. It was chosen due to this complexity, and as a representation of other VR films produced by environmental NGOs, which often feature emotive content in 'pristine' environments.

6.2.2 Participants

101 participants were recruited in total (VR: n=47, control: n=54) with full demographic breakdown in Table 8.

Demographic		VR	Control
Gender	Female	24	29
	Male	23	23
Age	18-24	7	8
	25-34	19	21
	35-44	8	14
	45-54	8	7
	55-64	3	3
	65+	1	0
	N/S	1	1
Highest general qualification	GCSE/O-Level	4	9
	Vocational/NVQ	4	3
	A-Level/Higher/BTEC	5	15
	Degree or Equivalent	20	14
	Postgraduate Qualification	12	9
	Other	1	0
	No Formal Qualifications	1	2
	N/S	0	2

Table 8 Demographic breakdown across VR and control groups (number of participants).

6.2.2.1 Previous VR use

Participants were asked to report their frequency of VR use, to ascertain if any significant differences between groups could impact outcomes. The frequencies are reported in Table 9, however due to the data distribution failing the requirements for chi squared test of independence (e.g. 80% of data points

being above 5, and all being above 1), the data fails the assumptions required for a chi squared test (Pallant, 2020).

	VR	Control
Rarely	22	22
More than once a month	15	17
More than once a week	9	12
Every day	0	3

Table 9 Frequency of VR use between the control and VR groups (number of respondents per category).

6.3 Results

Results are structured by research question (and then by relevant metrics for the dependent variables within the Kollmuss and Agyeman (2002) model), followed by an exploration of the qualitative findings which cut across both RQs. Correlations between variables can be found in Table 10 Correlation coefficients across selected dependent variables (r) ** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed). Cronbach's alpha on the diagonal.

10, and details of the analysis methodology can be found in the Appendices.

		1	2	3	4	5	6	7	8	9	10
1 Repeated Environmental Behaviour Scale	r (sig.)	1 (α=0.76)									
2 Meat attitude	r (sig)	-0.068 (0.671)	1 (α=0.89)								
3 Vegetarian attitude	r (sig)	0.22 (0.166)	**-.403** (0.007)**	1 (α=0.87)							
4 Vegan attitude	r (sig)	0.154 (0.336)	**-.388* (0.01)**	**.856** (0.00)**	1 (α=0.89)						
5 New Ecological Paradigm Scale	r (sig)	0.142 (0.371)	-0.139 (0.375)	**.426** (0.004)**	**.331* (0.03)**	1 (α=0.83)					
6 Connection to Nature Scale	r (Sig)	0.191 (0.215)	0.108 (0.503)	0.001 (0.995)	-0.061 (0.706)	**.386* (.011)**	1 (α=0.86)				
7 Knowledge cause	r (sig)	0.102 (0.512)	-0.011 (0.947)	0.084 (0.601)	0.119 (0.457)	0.157 (0.322)	-0.111 (0.472)	1 (α=0.49)			
8 Knowledge impact	r (Sig)	0.056 (0.72)	0.093 (0.565)	-0.039 (0.808)	-0.002 (0.988)	-0.005 (0.976)	-0.174 (0.259)	**.396** (0.008)**	1 (α=0.55)		
9 Knowledge response	r (Sig)	-0.044 (0.779)	-0.027 (0.869)	0.176 (0.271)	0.137 (0.391)	**.431** (0.004)**	0.263 (0.084)	**.318* (0.036)**	**.506** (0.000)**	1 (α=0.51)	
10 Psychological Distance	r (Sig)	-0.176 (0.254)	-0.029(0.856)	-0.155 (0.333)	-0.133 (0.406)	0.243 (0.12)	0.238 (0.119)	0.192 (0.211)	0.158 (0.304)	0.146 (0.344)	1 (α=0.80)

Table 10 Correlation coefficients across selected dependent variables (r) ** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed). Cronbach's alpha on the diagonal.

	Time 1		Time 2		Time 3	
Mean scores	**VR**	**Control**	**VR**	**Control**	**VR**	**Control**
REBS	3.05 (0.38)	2.97 (0.45)	--	--	3.04 (0.41)	2.97 (0.50)
Meat attitudes	3.23 (1.13)	3.53 (1.16)	--	--	3.12 (1.33)	2.81 (1.70)
Vegan attitudes	3.04 (1.04)	2.91 (1.24)	--	--	2.38 (1.28)	2.24 (1.50)
Vegetarian attitudes	3.65 (0.94)	3.36 (1.04)	--	--	2.90 (1.36)	2.59 (1.51)
Vegetarian eating intention	2.13 (1.57)	2.11 (1.39)	--	--	2.14 (1.40)	1.71 (1.48)
NEP	3.74 (0.61)	3.72 (0.61)	3.81 (0.68)	--	3.76 (0.62)	3.61 (0.64)
CNS	3.47 (0.64)	3.43 (0.61)	3.59 (0.65)	--	3.33 (0.68)	3.32 (0.65)
Env Knowledge - cause	6.89 (1.27)	6.98 (1.74)	6.77 (1.20)	--	6.75 (1.40)	6.72 (1.57)
Env Knowledge - impact	7.05 (1.95)	6.87 (1.86)	7.07 (1.25)	--	7.00 (1.97)	6.48 (2.00)
Env Knowledge - response	9.27 (1.30)	9.00 (2.12)	9.43 (0.94)	--	8.98 (1.83)	8.78 (2.00)
Psychological Distance	2.54 (0.64)	2.41 (0.77)	2.37 (0.70)	--	2.46 (0.73)	2.51 (0.73)

Table 11 Summary of mean scores (and standard deviation) per variable and condition over time.

6.3.1 RQ7: What are the effects of an environmental VR intervention over time on behavioural determinants and outcomes?

6.3.1.1 Pro-environmental behaviour

Pro-environmental behaviour was measured through the Recurring Pro-Environmental Behaviour Scale (REBS) using 21 questions measuring behaviour across a range of domains. Data was collected at pre-test (T1) and at the 3 weeks later time point (T3). The metric measures self-reported behaviours, and higher values correspond to higher self-reported pro-environmental behaviour (Table 12). The Recurring Pro-Environmental Behaviour Scale (REBS) was found to have a moderately high internal consistency (Cronbach's α=0.76). A Shapiro-Wilk's test found the VR group's data to be normally distributed, whereas the control group was non-normally distributed, therefore both parametric and non-parametric tests are conducted.

Considering the VR group over time; a paired samples t-test with data at Time 1 (M=2.95, SD=0.38) and Time 3 (M=2.98, M=0.41), found a non-significant difference between time points (t(43) = 0.05, p = 0.96 (two-tailed)). A Wilcoxon signed rank test (due to non-normally distributed data) found a non-significant difference between T1 and T3 within the control group (z = -0.520, n = 46, p = 0.603).

Condition	T1 (M (SD))	T3 (M (SD))
CONTROL	2.97 (0.45)	2.97 (0.50)
VR	3.05 (0.38)	3.04 (0.41)

Table 12 Mean and standard deviations across VR and control conditions over time (T1 and T3).

A Mann-Whitney U-test found no significant difference between the VR and control conditions at both T1 (U = 1072.500, z = 0.489, p = 0.625) and T3 (U = 1067.000, z = 0.444, p = 0.657).

6.3.1.2 Meat Consumption

Several metrics relating to meat consumption were measured; including attitudes to meat (based on Povey et al., 2001), self-reported weekly meat consumption, and vegetarian diet intention.

6.3.1.2.1 Attitudes to different diets

Attitudes to meat, vegetarian and vegan diets were measured at pre-test (T1; both groups), post-test (T2; VR only), and repeated measure (T3; both groups). This was measured using the question: “How would you rate a [meat/vegetarian/vegan] diet?”, on a scale of 1-7 across four components, which has been standardised to a 1-5 Likert scale. The measure of attitudes to meat consumption were found to have very good internal consistency (Cronbach's alpha; meat diet: α= 0.89; vegetarian diet: α= 0.87; vegan diet: α=0.89). Higher scores correspond to more positive associations with that diet.

MEAT	T1 (M (SD))	T3 (M (SD))
CONTROL	3.53 (1.16)	2.81 (1.70)
VR	3.23 (1.13)	3.12 (1.33)
VEGETARIAN		
CONTROL	3.36 (1.04)	2.59 (1.51)
VR	3.65 (0.94)	2.90 (1.36)
VEGAN		
CONTROL	2.91 (1.24)	2.24 (1.50)
VR	3.04 (1.04)	2.38 (1.28)

Table 13 Attitudes to diets, mean and standard deviations across condition and T1 and T3.

6.3.1.2.1.1 Attitudes to meat diets

Across both conditions, the data was non-normally distributed (Kolmogorov-Smirnov test: VR T1 ($p = 0.041$), VR T3 ($p = 0.037$), control T1 ($p < 0.001$), control T3 ($p = 0.005$)), therefore non-parametric tests are used. Comparing the effect over time, the Wilcoxon signed rank test found a statistically significant reduction in positive attitudes between control T1 and T3 ($z = -2.282$, $n = 51$, $p = 0.022$). However, the Wilcoxon signed rank test found no statistically significant difference between VR T1 and T3 ($z = -1.307$, $n = 47$, $p = 0.191$).

Comparing the VR and control conditions, Mann-Whitney U-tests found that there was no statistically significant difference between the VR and control groups at T1 ($U = 1004.000$, $z = -1.532$, $p = 0.126$) or T3 ($U = 1150.000$, $z = -0.346$, $p = 0.730$).

6.3.1.2.1.2 Attitudes to vegetarian diets

Across both conditions, the data was primarily normally distributed (Kolmogorov-Smirnov test: VR T1 (p = 0.200), Control T1 (p = 0.200), Control T3 (p = 0.066)), aside from VR T3 (p = 0.034)) therefore parametric tests are used.

A paired samples t-test found that there was a statistically significant reduction in positive attitudes between T1 and T3 in both the control (t(50) = 3.866, p < 0.001 (two-tailed)) and VR (t(46) = 3.360, p = 0.002 (two-tailed)) conditions.

Comparing the VR and control conditions, independent sample t-tests found non-significant differences between groups at T1 ((t)99 = 1.360, p = 0.177) and T3 ((t)95 = 1.399, p = 0.165).

6.3.1.2.1.3 Attitudes to vegan diets

Across both conditions, the data was all normally distributed (Kolmogorov-Smirnov test: VR T1 (p = 0.200), VR T3 (p = 0.200), Control T1 (p = 0.200), Control T3 (p = 0.185)), therefore parametric tests are used.

A paired samples t-test found that there was a statistically significant difference between T1 and T3 in both the control (t(50) = 4.163, p < 0.001 (two-tailed)) and VR (t(46) = 3.110, p = 0.003 (two-tailed)) conditions, indicating a significant negative change in attitudes towards vegan diets across both conditions over time.

Comparing the VR and control conditions, independent sample t-tests found non-significant differences between groups at T1 ((t)97 = -0.557, p = 0.579) and T3 ((t)96 = -0.865, p = 0.389).

6.3.1.2.1.4 Meat-eaters change in attitudes

As data on self-reported meat consumption was collected, this enabled 11 participants who reported themselves to ‘never’ eat meat to be removed, and the data analysis re-run to explore the effect (if any) on meat-eaters alone.

MEAT	T1 (M (SD))	T3 (M (SD))
CONTROL	3.75 (0.92)	3.04 (1.40)
VR	3.50 (0.91)	3.00 (1.71)
VEGGIE		
CONTROL	3.23 (0.99)	2.49 (1.45)
VR	3.49 (0.90)	2.84 (1.42)
VEGAN		
CONTROL	2.77 (1.16)	2.06 (1.38)
VR	2.88 (1.02)	2.32 (1.32)

Table 14 Diet attitudes (without vegans and vegetarians) mean and standard deviation across conditions (at T1 and T3).

Meat diet attitude

Across the conditions, the data was primarily normally distributed (Kolmogorov-Smirnov test: VR T1 (p = 0.186), Control T1 (p = 0.010), Control T3 (p = 0.002)), aside from VR T3 (p = 0.002) which was non-normally distributed, therefore parametric tests are used.

In the VR condition, a paired sample t-test found a statistically significant decrease from T1 (M = 3.50, SD = 0.914) to T3 (M = 3.00, SD = 1.71) (t(40) = 2.475, p = 0.018, Cohen's d = 0.365), indicating a negative change in attitudes to meat diets in the VR condition over time, with a small-medium effect size.

In the control condition, a paired sample t-test found a statistically significant difference from T1 (M = 3.75, SD = 0.922) to T3 (M = 3.04, SD = 1.40) (t(46) = 3.136, p = 0.003, Cohen's d = 0.599), indicating a negative change in attitudes to meat diets in the control condition over time, with a large effect size.

Comparing the VR and control conditions, independent sample t-tests found non-significant differences between groups at T1 ((t)87 = 1.316, p = 0.192) and T3 ((t)86 = -0.111, p = 0.912).

Vegetarian diet attitude

Across the conditions, the data was both normally distributed (Kolmogorov-Smirnov test: VR T1 (p = 0.200), Control T1 (p = 0.200), Control T3 (p = 0.052)), and non-normally distributed (VR T3 (p = 0.045)), therefore parametric tests are used.

Considering the VR condition, a paired sample t-test found a statistically significant decrease from T1 (M = 3.49, SD = 0.90) to T3 (M = 2.84, SD = 1.42) (t(40) = 3.199, p = 0.003, Cohen's d = 0.547), indicating a negative change in attitudes to vegetarian diets in the VR condition over time, with a medium effect size.

Considering the control condition, a paired sample t-test found a statistically significant difference from T1 (M = 3.23, SD = 0.99) to T3 (M = 2.49, SD = 1.45) (t(46) = 3.693, p < 0.001, Cohen's d = 0.596), indicating a negative change in attitudes to vegetarian diets in the control condition over time, with a large effect size.

Comparing the VR and control conditions, independent sample t-tests found non-significant differences between groups at T1 ((t)87 = -1.257, p = 0.212) and T3 ((t)86 = -1.148, p = 0.254).

Vegan diet attitude

Both conditions were normally distributed (Kolmogorov-Smirnov test: Control T1 (p = 0.200), Control T3 (p = 0.186), VR T1 (p = 0.200), VR T3 (p = 0.200)), therefore parametric tests are used.

Considering the VR condition, a paired sample t-test found a statistically significant decrease from T1 (M = 2.88, SD = 1.02) to T3 (M = 2.32, SD = 1.32) (t(40) = 2.890, p = 0.006, Cohen's d = 0.475), indicating a negative change in attitudes to vegan diets in the VR condition over time, with a medium effect size.

Considering the control condition, a paired sample t-test found a statistically significant difference from T1 (M = 2.77, SD = 1.16) to T3 (M = 2.06 SD = 1.38) (t(46) = 4.089, p < 0.001, Cohen's d = 0.557), indicating a negative change in attitudes to vegan diets in the control condition over time, with a medium effect size.

Comparing the VR and control conditions, independent sample t-tests found non-significant differences between groups at T1 ((t)87 = -0.567, p = 0.573) and T3 ((t)86 = -0.907, p = 0.367).

Across all three diets, statistically significant differences were shown as attitudes to all diets became more negative over time, however, no significant differences were found across the conditions therefore the VR experience had no effect on attitudes to different diets.

6.3.1.2.2 Intention to eat a vegetarian diet

Respondents were asked "I intend to eat a vegetarian diet in the future…", on a 1-7 Likert scale which has been standardised to 1-5 (1=strongly disagree, 5=strongly agree).

Condition	T1	T3
VR	2.13 (1.57)	2.14 (1.40)
CONTROL	2.11 (1.39)	1.71 (1.48)

Table 15 Intention to eat a vegetarian diet, at T1 and T3 across conditions (mean and (standard deviation)).

All data was non-normally distributed therefore non-parametric tests are required.

A Wilcoxon-signed rank test found a non-significant difference between VR Time 1 and Time 3 (z=0.994, n=44, p=0.320), however the control group was found to have a statistically significant difference over time (z=2.769, n=46, p=0.006).

This implies that the VR groups intention to eat a vegetarian diet in the future remained stable over time whereas the control group reduced significantly over time, potentially due to social desirability biases at T1.

6.3.1.2.3 Self-reported meat consumption

Respondents were asked to report on their weekly meat consumption. Over time, the VR group's self-reported meat consumption increased (**Error! Reference source not found.**), whereas the control group's remained stable at the extreme of the meat consumption frequencies (I eat meat never, rarely, and

more than once a day). The greatest shift was in the middle frequencies (I eat meat ‘less than 3 times a week’, ‘more than three times a week’, and ‘once a day’), where both groups shifted towards more frequent meat consumption, although the VR group increased more. This aligns with the analysis above which found a decrease in positive attitudes towards vegetarian and vegan diets, with meat diets remaining more stable.

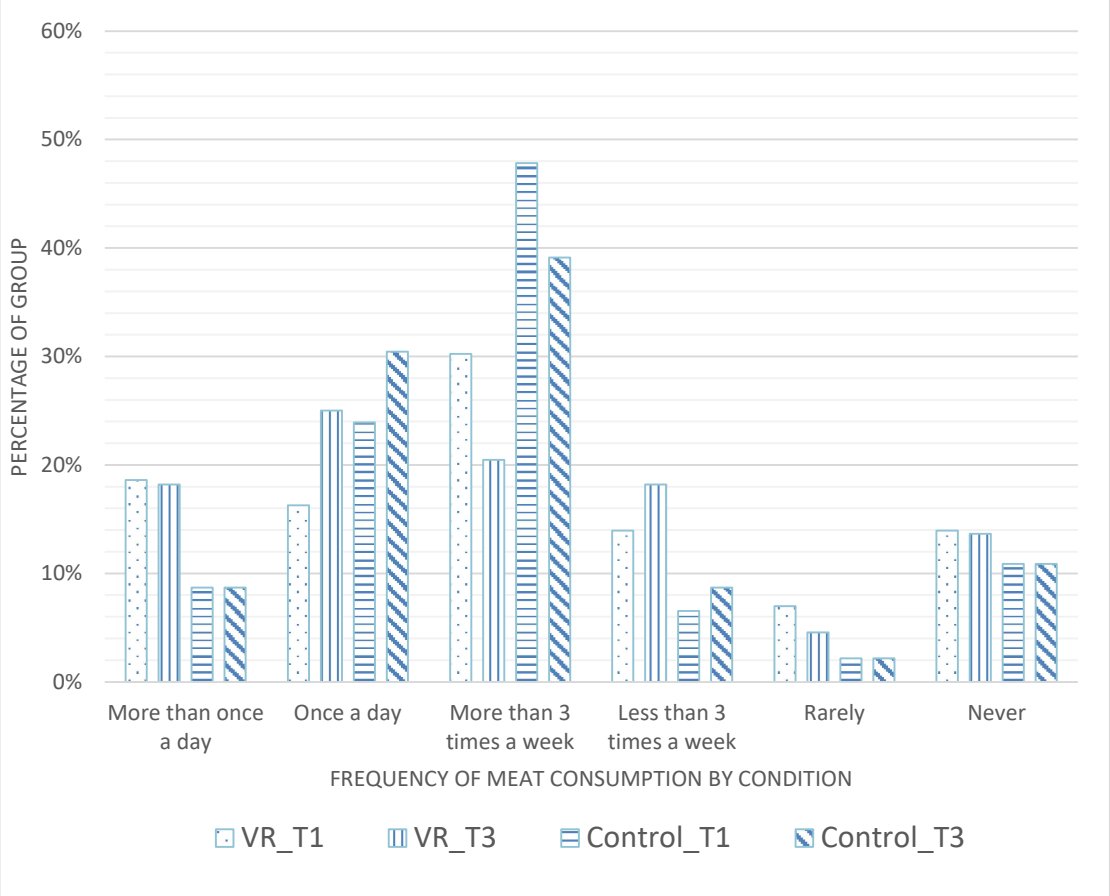


Figure 9 Mean self-reported meat consumption; by group and time condition.

Looking at these measures collectively, it paints a complex picture, with the potential for factors such as social desirability biases and reporting ceilings being reached playing a role. The differential response between the control and VR groups to diet attitudes as well as self-reported meat consumption, could indicate a values-based adjustment in respondents’ post-intervention results (e.g. a respondent reflecting more carefully on their own behaviours and reporting more accurately). This complex picture warrants further research into the role of social desirability biases and other variables difficult to control and measure in a virtual experimental setting.

6.3.1.3 Behavioural determinants

Three behavioural determinants were also measured: attitudes (Revised New Ecological Paradigm scale), values (Connectedness to Nature Scale), and knowledge (environmental knowledge metric).

6.3.1.3.1 Environmental attitudes – revised New Ecological Paradigm Scale

Environmental values were measured using the revised New Ecological Paradigm Scale, and it was found to have good internal consistency (Cronbach's α=0.83). All data groups were normally distributed therefore parametric tests were used. **Error! Reference source not found.** shows the mean NEP scores for each condition over time, where higher scores correspond to more positive environmental values held.

Condition	T1	T2	T3
VR	3.74 (0.61)	3.81 (0.68)	3.76 (0.62)
CONTROL	3.72 (0.61)	--	3.61 (0.64)

Table 16 Revised New Ecological Paradigm scores across all data points (mean (standard deviation)).

Across the conditions, the data was primarily normally distributed (Kolmogorov-Smirnov test: Control T1 (p = 0.200), VR T2 (p = 0.089), Control T3 (p = 0.200), VR T3 (p = 0.200), and non-normally distributed (VR T1 (p = 0.027)), therefore parametric tests are used.

To examine the effect of the intervention on the VR group over time, a one-way repeated measures ANOVA was conducted on the VR group. A non-significant effect was found across Time 1, 2 and 3 (Wilks' lambda = 0.955, F(2, 42) = 0.990, p=0.380, multivariate partial eta squared 0.045). Multiple paired sample t-tests were conducted which found that the increase in NEP scores was non-significant across all comparisons (T1-T2 (t(46)=-1.487, p=0.144 (two tailed); T2-T3 (t(43) = 0.498, p = 0.621); and T1 – T3 (t(43) = -0.495, p = 0.623).

A paired samples t-test found no significant differences between the control condition at T1 (M = 3.68, SD = 0.635) and T3 (3.61, SD = 0.644) (t(45) = 1.258, p = 0.215).

Independent sample t tests were used to examine the differences between the control and VR condition, at T1 and T3. At T1 it found no significant difference between control (M = 3.72, SD = 0.613) and VR (M = 3.74, SD = 0.598) (t(99) = 0.116, p = 0.908). At T3 it found no significant difference between the control (M = 3.61, SD = 0.644) and VR (M = 3.76, SD = 0.615) (t(88) = 1.186, p = 0.239).

6.3.1.3.2 Connectedness to Nature scale

Connectedness to Nature is used as a measure of values due to the content of the VR intervention heavily leaning on nature as a theme, and was initially developed by Mayer and Frantz (2004). The Connection to Nature Scale (CNS) had a good internal validity (Cronbach's alpha α=0.86), where a higher score represents a higher connectedness with nature. It was calculated by measuring across 15 indicators, and includes some reverse coded questions, and is measured on a 1-5 Likert scale (as in Ahn et al., 2016) (Table 17).

Condition	T1	T2	T3
VR	3.47 (0.64)	3.59 (0.65)	3.33 (0.68)
CONTROL	3.43 (0.61)	--	3.32 (0.65)

Table 17 Connectedness to nature scores across all data points (mean (standard deviation)).

Across the conditions, the data was normally distributed (Kolmogorov-Smirnov test: Control T1 (p = 0.875), VR T1 (p = 0.190), VR T2 (p = 0.107), Control T3 (p = 0.485), VR T3 (p = 0.107), therefore parametric tests are used.

To test the effect of the VR intervention over time, a one-way repeated measures ANOVA compared VR group scores over time (T1, T2, T3), as the data was normally distributed. This found a significant effect over time (Wilks' Lambda = 0.725, F(2, 42)=7.982, p=0.001, multivariate partial eta squared = 0.275). Multiple paired t-tests with the VR group over time found that the decay effect from T2 (M=3.593, SD=0.651), to T3 (M=3.330, SD=0.678) was significant (t(43)=3.785, p<0.001 (two tailed)), indicating a significant reduction in connectedness. Whereas the increase in CNS from T1 – T2 (t(46)=-1.788, p=0.080) was non-significant, as was T1-T3 (t(43)=1.726, p=0.091).

When comparing the control group over time, a paired sample t test found there was no significant difference over time between T1 (M = 4.32, SD = 0.613) and T2 (M = 3.32, SD = 0.647) (t(46) = 1.409, p = 0.166).

In order to examine the effect across groups, independent t-tests were conducted. Non-significant differences were found over time(T1: t(99) = 0.635, p = 0.527; T2: t(99) = 1.431, p = 0.159; T3: t(88) = 0.104, p = 0.917), however the comparison at T2 was approaching significance (p = 0.159).

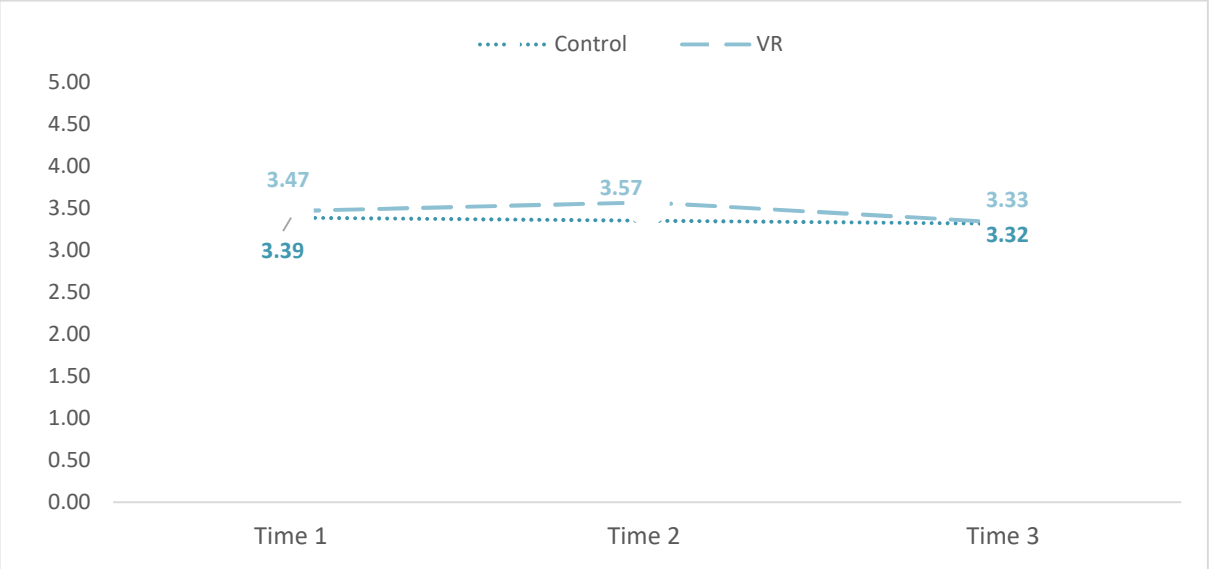


Figure 10 Connection to Nature Scale scores by condition over time (means).

6.3.1.3.3 Environmental knowledge

Environmental knowledge was measured across three components (cause, impact, response), which were analysed separately, and responses were categorised as either correct (1) or incorrect (0), and scores were calculated by adding total correct answers, therefore 13 was the maximum possible score for each scale. Internal consistency was found to be poor (cause: α=0.49, impact: α=0.55, response: α=0.51), which could affect the reliability of these assessments, however this is similar to other users of this metric (e.g. Xie et al., 2019). This could be somewhat explained by the mismatch between how the measure is constructed with ordinal survey answers analysed dichotomously (i.e. right/wrong).

6.3.1.3.3.1 Cause

Condition	T1	T2	T3
VR	6.89 (1.27)	6.77 (1.20)	6.75 (1.40)
CONTROL	6.98 (1.74)	--	6.72 (1.57)

Table 18 Environmental knowledge (cause) scores across all data points (mean (standard deviation)).

Across all conditions, the data was primarily non-normally distributed (Kolmogorov-Smirnov test: Control T1 ($p < 0.001$), VR T1 ($p < 0.001$), VR T2 ($p < 0.001$), Control T3 ($p < 0.001$), VR T3 ($p < 0.001$), therefore non-parametric tests are used. To explore the effect on the VR group of the intervention over time, a Friedman's Two-way analysis of variance by ranks was conducted across T1, T2 and T3, however this found a non-significant difference (χ^2 (2, n=44) = 2.646, p = 0.266). Similarly, paired tests (Wilcoxon signed rank tests) were conducted, were also non-significant (T1-T2: z = -0.951, n = 44, p = 0.342; T2-T3: z = 0.034, n = 44, p = 0.973). Exploring the effect of time in the control group, a Wilcoxon signed rank test found no significant difference between T1 and T3 (z =1.309, n = 46, p = 0.191).

In order to explore the difference between the control and intervention, multiple Mann-Whitney U tests explored the difference between the VR and control groups, and no statistically significant difference was found at each time point (Time 1: U=1050.500, z=0.320, p=0.749; Time 3: U=1118.500, z=0.909, p=0.363).

6.3.1.3.3.2 Climate Impact

Condition	T1	T2	T3
VR	7.05 (1.95)	7.07 (1.25)	7.00 (1.97)
CONTROL	6.87 (1.86)	--	6.48 (2.00)

Table 19 Environmental knowledge (impact) scores across all data points (mean (standard deviation)).

Across all conditions, the data was primarily non-normally distributed (Kolmogorov-Smirnov test: Control T1 ($p < 0.001$), VR T1 ($p = 0.001$), VR T2 (p

= 0.001), Control T3 (p = 0.006), VR T3 (p = 0.060), therefore non-parametric tests are used.

The measure of knowledge of climate impacts found, through a Friedman's test, there was no significant difference over time within the VR group (χ^2 (2, n=44) = 2.352, p=0.309). Multiple Wilcoxon signed rank tests were conducted which found no significant difference over time (T1-T2: z = -0.354, n = 44, p = 0.724; T2-T3: z = -.244, n = 44, p = 0.807; T1-T3: z = -0.808, n = 44, p = 0.419). However, a Wilcoxon signed rank test found a statistically significant difference in the control group over time (T1 – T3: z = -2.118, n = 46, p = 0.034). This reduction in environmental knowledge over time could be affected by the poor internal consistency of the metric, or a variety of testing effects.

In order to compare the effect between groups, Mann-Whitney tests found no significant difference between groups at each time point (T1: U = 1079.000, z = 0.747, p = 0.455; T3: U = 1185.000, z = 1.637, p = 0.102), although T3 was approaching significance (p=0.102).

6.3.1.3.3.3 Response to climate change

Condition	T1	T2	T3
VR	9.27 (1.30)	9.43 (0.94)	8.98 (1.83)
CONTROL	9.00 (2.12)	--	8.78 (2.00)

Table 20 Environmental knowledge (response) scores across all data points (mean (standard deviation)).

Across all conditions, the data was primarily non-normally distributed (Kolmogorov-Smirnov test: Control T1 (p < 0.001), VR T1 (p = 0.002), VR T2 (p < 0.001), Control T3 (p < 0.001), VR T3 (p < 0.001), therefore non-parametric tests are used.

The measure of knowledge of response to climate change found, again through a Friedman's test, there was a non-significant difference over time within the VR group (χ^2 (2, n = 44) = 0.945, p = 0.623). Multiple Wilcoxon signed rank tests found no significant difference between the timepoints in the VR condition (T1-T2: z = 0.920, n = 44, p = 0.358; T1-T3: z = -0.895, n = 44, p = 0.371; T2-T3: z = 1.482, n = 44, p = 0.138). A Wilcoxon signed rank test found no significant difference in the control group over time (T1-T3: z = -0.907, n = 46, p = 0.364).

Comparing the effects between groups over time, Mann-Whitney tests were conducted, which found no significant differences (T1: U = 975.500, z = -0.310, p = 0.757; Time 3: U = 936.000, z = -0.657, p = 0.511).

6.3.1.4 Presence

Presence was measured using 14-item metric on a 1-7 Likert scale, where the higher the figure, the higher the presence felt (with an acceptable internal consistency of α = 0.716). Presence was shown to be consistently high (Table 21)

Item	mean	standard deviation
How involved were you in the virtual environment experience?	5.37	1.39
How completely were all of your senses engaged?	5.24	1.18
How much did the visual aspects of the environment involve you?	5.57	1.01
How much did the auditory aspects of the environment involve you?	5.43	1.19
How inconsistent or disconnected was the information coming from your various senses? [reversed]	4.26	1.66
How much did your experiences in the virtual environment seem consistent with your real-world experiences?	4.91	1.40
To what degree did you feel confused or disoriented during the experimental session? [reversed]	5.61	1.55
How completely were you able to actively survey or search the environment using vision?	5.46	1.16
How well could you identify sounds?	5.54	1.08
How well could you localize sounds?	5.11	1.39
How aware were you of events occurring in the real world around you? [reversed]	4.07	1.81
How aware were you of your display devices? [reversed]	4.20	1.74
How well could you concentrate on the video itself rather than on the mechanisms used to display that video?	5.48	1.35

Table 21 Mean and standard deviations of presence scale items.

These findings were used in concert with an open question ('did you have any technical issues?') in order to identify any participants who had technical problems which would affect immersiveness and therefore their experience. None were found and all participants were included in the final analysis.

6.3.2 RQ8: What are the effects of an environmental VR intervention on psychological distance?

Psychological distance was measured using the metric developed by Spence et al. (2012), as it is often used as part of other metrics developed to measure psychological distance (Keller et al., 2022). It was measured on 1-5 Likert scales (with the exception of one item which has not been standardised in order to enable comparison to other studies) and was found to have good internal consistency (Cronbach's alpha α=0.80). A higher score represents a higher psychological distance (and therefore lower pro-environmental indicator).

Condition	T1	T2	T3
VR	2.54 (0.64)	2.37 (0.70)	2.46 (0.73)
Control	2.41 (0.77)	--	2.51 (0.73)

Table 22 Psychological distance scores over time, by condition (mean (standard deviation)).

The mean total psychological distance scores by condition over time are shown in Table 22. Across most conditions, the data was primarily normally distributed (Kolmogorov-Smirnov test: Control T1 ($p = 0.200$), Control T3 ($p = 0.077$), VR T1 ($p = 0.200$), VR T3 ($p = 0.200$), aside from VR T2 ($p = 0.003$), which was non-normally distributed, therefore parametric tests are used.

A one-way repeated measures ANOVA was used to compare the VR group scores over time. This found an effect approaching significance for time (Wilks' Lambda = 0.874, $F(2, 42) = 3.018$, $p = 0.060$, multivariate partial eta squared = 0.126). Multiple paired samples t-tests were used to evaluate the impact of the VR on psychological distance. This found a statistically significant decrease in psychological distance felt between T1 ($M = 2.54$, $SD = 0.64$) and T2 ($M = 2.37$,

SD = 0.70) (t(46) = 2.111, p = 0.04), with a medium effect size (Cohens' d = 0.551) (using Cohen (1988) criteria for effect sizes (Pek and Flora, 2018)). No significant differences were found between T2 and T3 (2.46, SD = 0.73), (t(43) = -1.061, p = 0.295), nor T1 and T3 (t(43) = 1.133, p = 0.264). Exploring the control group over time, a paired sample t-test found a non-significant difference between T1 (M = 2.45, SD = 0.79) and T3 (M = 2.51, SD = 0.73) (t(45) = -0.712, p = 0.480).

In order to examine the effect of the condition, independent sample t-tests were conducted. This found no significant differences between the groups at both T1 (Control: M = 2.41, SD = 0.77; VR: M = 2.54, SD = 0.64) (t(99) = 0.935, p = 0.352) and T3 (Control: M = 2.51, SD = 0.73; VR: M = 2.46, SD = 0.73) (t(88) = -0.367, p = 0.714).

6.3.2.1 Components of psychological distance

Psychological distance is composed of four components, which are analysed in more depth in turn. The four components of psychological distance were measured (temporal, social, geographic and uncertainty) at T1 (control and VR), T2 (VR) and T3 (control and VR). Breaking psychological distance down by component suggests that geographic and social distance are greater than uncertainty and temporal distance, and this remains consistent over the repeated measures (Figure 11).

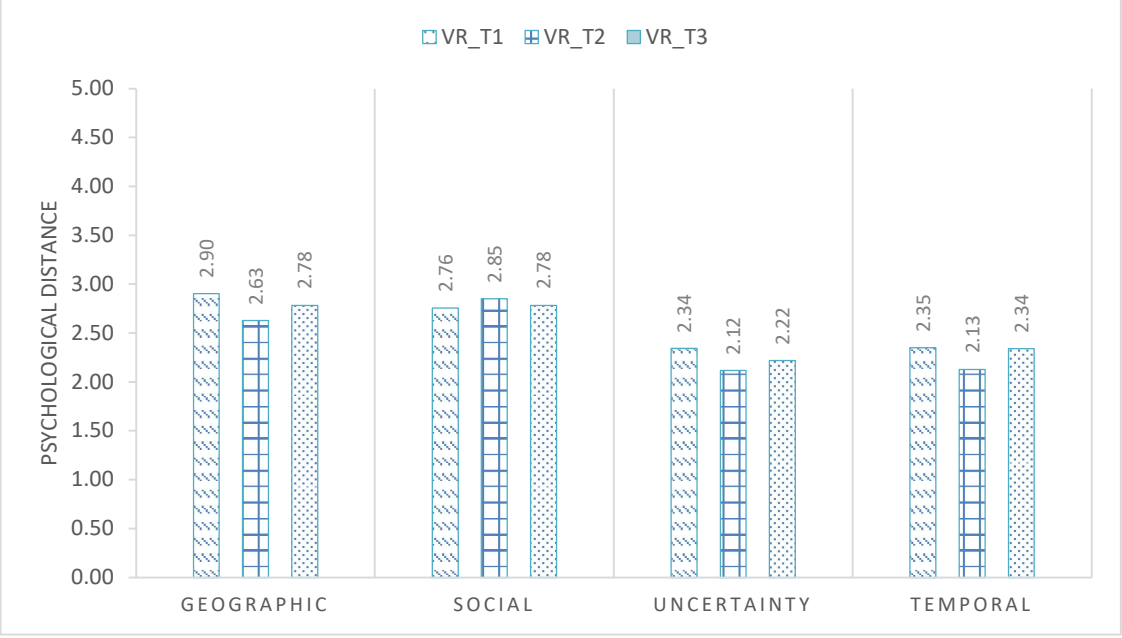


Figure 11 Psychological distance measures from VR condition, over time by component.

A one-way between-groups multivariate analysis of variance (MANOVA) explored all the components of the psychological distance metric (dependent variables) with condition as the independent variable (VR or control). Box's test of equality of covariance metrics found the data did not violate the assumption of homogeneity of variance-covariance. There were some outliers but due to the sample size being sufficient, these data points were included in the analysis. No statistically significant differences were found between groups (as a combined metric of psychological distance) ($F (3, 97) = 1.614$, $p = 0.116$, Wilks' Lambda = 0.842, partial eta squared = 0.158) however it was approaching significance. However, when exploring the components individually (the 10 questions which make up the metric of psychological distance) two questions were identified as being statistically significant. These were "it is uncertain what the effects of climate change will be" ($F (1, 97) = 4.028$, $p = 0.048$, partial eta squared = 0.041) and "climate change will mostly affect developing countries" ($F (1, 97) = 5.372$, $p = 0.023$, partial eta squared = 0.054). A third component approached significance ("Climate change will mostly affect areas that are far away from here.") ($F (1,97) = 3.705$, $p = 0.057$, partial eta squared = 0.038).

6.3.2.2 Experiential findings

The Self-Assessment Manikin (SAM) measured emotional response to the intervention (1=negative feelings – 9=positive feelings, n=45), initially developed by Bradley and Lang (1994) and adapted by Giacomin and Bertola (2012). The results showed that very few respondents felt positive emotions about the experience (9%, 7-9 score), with 40% feeling neutral (4-6 score), and 51% feeling negative (1-3 score) about the experience. This contrasts with the qualitative responses which were overwhelmingly emotional and negative.

6.3.2.3 Qualitative findings

Three qualitative questions were asked to provide greater depth and context for the quantitative findings:

- 'How did the film make you feel?',
- 'What thoughts did the film provoke?', and
- 'What message do you think the film is trying to convey?'.

These were completed immediately post-test and analysed through both inductive and deductive thematic analysis. A priori themes which were used were in reference to psychological distance and notions of individual behaviour change.

In response to “How did the film make you feel?”, the majority of the responses could be classed as negative emotions (n=31, N=54), some felt mixed emotions, most commonly positive about the experience combined with sadness about the content (n=7). There were some overall positive reactions to the experience (n=6), as well as some indifference (n=2). Participants were often classified within multiple themes. The overwhelmingly dominant theme was ‘sadness’, with 22 participants explicitly referencing sadness. Participants described their feelings as ‘sad’, ‘upset’, ‘depressed’, ‘despairing’, and this was sometimes also associated with sadness for others (e.g. the cows in the film, the rainforest) and sadness about others’ actions (e.g. “*The film made me feel sad, that we as a human race are destroying the earth so readily for our own selfish needs*”). Guilt (n=6) was also found as a strong theme, often contextualised within sadness. This manifested as guilt regarding meat consumption (e.g. “*guilty for eating meat*”), farming (e.g. “*slightly bad that I am funding the cattle commerce*”) as well as perception of own awareness (e.g. “*I feel like I don’t pay as much attention as I should to these issues*”). ‘Connection to nature’ was identified as a prominent cross-cutting theme (n=15), which manifested as guilt and sadness for the human impact on nature (n=10), awe (n=4), as well as feeling ‘emotional’ (n=5) (e.g. “*emotional and like I’m living the realities of climate change*”). Connection to nature was also felt through explicit reference to empathy with the cows in the film (n=5) in addition to guilt around meat eating or being part of a system which exploits the animals.

In terms of inspiring action, only 4 participants referenced their intention to now change their own behaviour (e.g. “*embraced changing the way I live”*). Secondary themes identified include concern (n=6), shock (n=4), anger (n=3) and reflection (n=3).

Categorising the data into personal (‘I’ statements), shared (‘we’/’our’ statements), and abstract (‘humans’/’people’ statements) responsibility found that 7 participants felt personal responsibility, 5 shared responsibility, and 8 felt that responsibility was abstract. Examples of these include:

“Shocked and slightly bad that I am funding the cattle commerce” (personal responsibility)

“It made me think more about how we can be kind to our planet” (shared responsibility)

“It made me feel sad that people are more interested in the benefits of today as supposed to the consequences in the future” (abstract/others responsibility)

The visceral and keenly emotional responses from the majority of participants draw a clear and consistent experience of the VR film.

Participant responses to ‘Q2: what thoughts did the film provoke?’ were consistent with the emotional responses in Q1. Many of the themes identified in Q1 are also common to Q2. Sadness was the dominant theme (n=15), however references to action and behaviour change were also prominent (n=11). Guilt (n=9) was also frequently referenced, in a similar vein to Q1, for instance through mentions of normative beliefs (e.g. “*I really should be making more of an effort”* and *“it provoked thoughts about how widespread this is and how much deforestation could be prevented if everyone cut back on waste and other non-essentials*”). Connection to nature was also a strong theme (n=7) (although much less prominently than in response to the emotional reaction in Q1), with references to nature as “*beautiful*”, “*wonderful*” and “*vast and varied*”, as well as anger at human impact on nature. There were also a smattering of secondary themes, categorized as anger (n=5), hope (n=2), concern (n=2) and cynicism (n=1).

In terms of notions of responsibility, I found a distinction between the ‘abstract’ (n=5) and ‘others’’ (n=6) responsibility found in Q1, more clearly within these responses. I themed these distinctly here as there were more in-depth answers which elucidated the responsibility implied, primarily through reference to an ‘owner’ (e.g. “*It's sad that the beautiful nature gets destroyed for someone's profit*”) as opposed to an abstract statement (e.g. “*I was sad and angry that the rainforest is being destroyed*”). Personal responsibility was felt much more clearly (n=14) (e.g. “*made me think about my own actions*”), and shared responsibility was also found to a lesser extent (n=6) (e.g. “*I considered the idea of it being so odd that we as a population give up such wonderful parts of nature just for the sake of eating meat*”).

Specifically, the link the participants made to their own actions were heavily skewed towards meat consumption behaviours (n=7) (e.g. “*I want to help to reduce the amount of cattle being produced and killed and trees killed*”; “*It made me think that that type of cattle is only made for fast food outlets like*

MacDonald's so I wouldn't ever eat meat from a cow from there"). There was also reference to generic 'change' (n=5) (e.g. "m*ade me think about my own actions*"), intentions to reduce deforestation (n=2) and information gathering (n=1).

The responses to Q3 ('What message do you think the film is trying to convey?') reflect the interrelated environmental and societal issues which the film touches on. In terms of the issues identified, deforestation was identified most commonly (n=16), followed by farming practices (n=12), meat consumption (n=8), climate change (n=6), broader consumption (n=2), societal impacts (n=2), animal welfare (n=1) and land degradation (n=1). A significant proportion of participants (n=19) identified more than one issue in the messaging, indicating the film was relatively effective at portraying the complexity of the issues. The most commonly identified related issues were farming and deforestation, as it could be argued this was the most explicit theme of the film and the two issues can be seen as cause and effect.

The discourse around responsibility continues through to this question with increasing prominence, due to the participants interpreting the VR messaging in the form of an 'action' and therefore referencing responsibility explicitly or implicitly. Within this question, I found the four themes matched those in Q2: personal responsibility, shared responsibility, others responsibility, and an abstract sense of responsibility. Abstract responses were most frequent (n=19), with interpretations of the VR message classified as either 'need for preservation/we need to save…' (e.g. "i*mportance of protecting the planet for future generations*") and 'understanding impact' (e.g. "*the negative impacts of cattle farming and thus the negative effects of a meat diet*"). Within the shared responsibility theme (n=16), this included references to collective impact (e.g. "*deforestation is a serious issue affecting our planet*") as well as collective action (e.g. *"We shouldn't be eating so much beef, or be cutting down the forest*"). The perspectives can be themed by anthropocentric (e.g. "*To save our planet", "The amount of natural resources we destroy to make more money causing changes in our environment and natural habitats and causes consequences to our home*") or nature-centric positions (e.g. "*That we are a part of nature, not in control of it*"); where anthropocentricism dominates primarily through notions of 'our planet', 'home' and 'what we could lose'. 'Other's responsibility' was identified slightly less than in the previous questions (n=7) with examples of the interpretation of the message including "*Informing what's happening in Brazil: the Amazon and suggesting that people should eat less meat to prevent destruction of the rain forest*", "*Trying to open people's eyes to what is being destroyed and how massive the beef production industry*

has become" and "*I think it's trying to make people feel sadness*". These interpretations refer to impact of human activities, the emotional response to the film, as well as explicitly referencing cause and effect. There were only a handful of responses which referenced the participants own responsibility (n=3) (e.g. "*To stop deforestation and to really consider the foods you eat as they have a big impact on the environment*"). This could indicate either an understanding of themselves in the collective (e.g. shared responsibility), or a gap in acknowledgement of their own responsibility to these issues.

6.4 Discussion

In this study, the effects of an environmental VR film on pro-environmental behaviour was examined, through a range of behavioural determinants and psychological distance, while considering behaviour holistically and dynamically, using the Kollmuss and Agyeman (2002) model of pro-environmental behaviour. VR is often assumed to bring distant experiences closer to the individual and bridge psychological distance associated with climate change and environmental issues, therefore I explored these assumptions and further the understanding around how VR can most effectively be used for pro-environmental communications.

Psychological distance was found to have a statistically significant difference within the VR condition over time from pre- to post-intervention (T1 to T2), indicating the VR experience reduced the distance people felt. The analysis of the components of psychological distance indicates that although there was no significant change over time, geographic and social distances were greater than uncertainty and temporal. This finding contributes to the small but growing research body exploring the impact of virtual reality on psychological distance, which has found mixed results. Breves and Schramm (2021) identified a reduction in psychological distance felt after an environmental VR experience, as do Raja and Carrico (2021) in their qualitative study. However, several studies have found no effect or inconclusive effects (e.g. Meijers et al. (2023), Plechatá et al. (2022)). This mirrors research on psychological distance more broadly, where a comprehensive systematic review identified inconsistent findings in relation to the impact of psychological distance on pro-environmental behaviours (Keller et al., 2022).

In exploring the effects of the VR intervention on behavioural determinants and behavioural outcomes, the results paint a complex picture. Significant changes over time were found across the diet attitudes metrics, where the control group had statistically significant reductions in positive attitudes to all three diets (meat, vegetarian, vegan) whereas the VR condition has a statistically significant reduction in positive attitudes to the vegetarian and vegan diets. There could be many possible explanations for this due to the potential for complex interactions occurring here, or there could be measurement errors or biases such as social desirability biases (Kaiser, 1998; Milfont, 2009). Removing the participants who self-declared as vegans resulted in the attitudes to meat diets becoming a statistically significant reduction in positive attitudes within the VR condition. These findings contradict those found by Plechatá et al.

(2022) who identified that an environmental-themed VR experience led to a positive change on diets over time.

Environmental knowledge (specifically the knowledge of the impacts of climate change) was found to reduce over time within the control group, although there were issues of internal validity within this metric, which could have affected these findings (similar internal validity for the metric was also found in Xie et al., 2019). Connection to nature was found to reduce from T1 to T3 in the VR group, and was approaching a significant increase between T1 and T2, and approaching a significant reduction between T2 and T3. This may have become significant with a larger sample size.

6.4.1 Connection to nature and psychological distance

The quantitative findings provide the context with which to explore the qualitative findings. The complexity in the data (e.g. with decreases in knowledge post-intervention, inconsistent trends in attitudes relating to meat consumption, and decay rates) is mirrored somewhat by the qualitative findings. The experiential survey question found 40% of respondents felt neutral about the experience, however, in the qualitative data, the words used were overwhelmingly emotional and negative (e.g. sad, depressed, guilty etc.). This reflects previous work which found (in a similar study) that 61% of respondents felt emotional responses, implicitly or explicitly to a nature-based VR piece (Raja and Carrico, 2021). Connection to nature was a key theme, which was anticipated due to the context of the VR film (geographically in the Amazon, conceptually centred on deforestation and meat production while presenting the narrative in an emotive way). Despite the dominance of nature in the qualitative findings, the experiment found an increase which was approaching significance in Connection to Nature from T1 to T2 in the VR condition, although the decay rate from T2 – T3 was also found to be approaching significance in the VR condition. This dissonance could be explored through the lens of the next key finding in the qualitative data, the distinction between individual, collective, and abstract responsibility. The Connection to Nature metric inherently examines the relationship between the individual (participant) and nature. However, I found that the participants were interpreting the message of the VR film from an abstract sense of responsibility most frequently (n=19), with shared responsibility second-most frequently (n=16), others' responsibility third (n=7), and individual responsibility being recognised far less (n=3). Therefore, despite the survey identifying no statistically significant positive effect on connection to nature, the majority of participants did experience an emotional connection to

nature; however, this did not directly translate into notions of individual responsibility. This dissonance of responsibility can be found across behavioural intervention literature, with (Howell, 2011) identifying action and responsibility as the key message that participants interpreted from a climate change film, however in this case individual responsibility was most prominent. The relationship between empathy and responsibility is examined in (Kandaurova and Lee, 2019) where the effect of VR was found to increase the responsibility to donate to charity, however this relationship was entirely mediated by empathy.

The dichotomy between an emotional connection to an issue without internalising a sense of responsibility, implies a cognitive gap in the behavioural process which may be explained (or explored) through the lens of psychological distance. The specific components within the measure of psychological distance found that geographic distance and uncertainty were significantly different over time. This somewhat corroborates Raja and Carrico's (2021) work who found that temporal distance and uncertainty lowered after a VR intervention. The specific context in which the VR experience works (i.e. what message the VR is portraying, and the broader context the viewer experiences the content) could significantly affect the individual impact, as there is no ‘one size fits all’ approach within pro-environmental VR content. This context will have been a distant experience, particularly geographically and socially (in the Amazon rainforest following cattle farmers) for most participants. However, despite considering the important role of the degree of distance present in the content, the use of VR has been shown to reduce psychological distance compared to unidirectional video (Breves and Schramm, 2021), however again only in the temporal dimension.

6.4.2 Recommendations

The findings present several practical implications for future environmental communications utilising virtual reality. The complexity of attitudinal response (e.g. reduction in positive attitudes to vegetarian and vegan diets when presented with a VR intervention with messaging around the negative impacts of cattle ranching) indicates the need for VR to be used in conjunction with other behavioural interventions which encourage and/or facilitate behaviour change immediately post-intervention. This could be in the form of specific ‘calls to action’ or other targeted outcomes which align with focused interventions. This corroborates Gregg et al.'s (2022) recommendations of utilising calls to action to

mitigate the risk of emotional responses such as guilt leading to apathy, within the context of conservation messaging.

I recommend future research explores behaviour in a complex and dynamic way. Only through exploring the interaction of behavioural determinants on behavioural outcomes, can high-impact behaviour change be effectively facilitated and supported. Crucial to this is the explicit exploration of psychological distance, and the continued testing of the assumptions that VR 'bridges the gap', with greater focus on the mechanics of this and potential rebound effects associated with reduced psychological distance. Specifically, although I recognise and empathise with the difficulties of conducting longitudinal work, my indicative findings around decay rates highlight a need for this to be explored in much greater depth, ideally with observed or otherwise measured behaviour.

6.4.3 Limitations

There are several limitations present within this work, some of which I have attempted to mitigate for. Due to Covid-19, the experiments were conducted virtually at the participants leisure (presumably often at home) and therefore experimental control is lower than it would have been in laboratory conditions. A part of this is the experiential variation associated with hardware and software differences, as presence has been found to be affected by frame rate and a range of other technological factors such as difference internet connectivity speeds (Shafer et al., 2019), however no participants reported technological issues. The self-selection of participants, and within that, the requirement for participants to have access to their own VR equipment presents a limitation. The frequency of use (Table 9) shows that the majority of participants 'rarely' used VR which mitigates this risk somewhat. The sample size is relatively small (N = 101); however, this is comparable or larger than several similar studies and was selected based on learnings from the systematic review (e.g. Ahn et al. (2014), Ahn et al. (2016), Bailey et al. (2015), Breves and Heber (2020)). There were cost limitations which led to a compromise between sample size and feasibility. The choice in the experimental design to utilise a negative control condition (i.e. no intervention), resulted in difficulty with data analysis due to no data at T2 (immediate post-test) for the control group. In future, I would recommend using a positive control and collecting data for both groups at T2. Using pre-existing validated metrics was a research design choice, in order to contribute to buildable research (Lange and Dewitte, 2019), however, the limitations inherent to those metrics are transferred to this study.

6.5 Conclusions

This research explored the impact of an environment-themed VR film on a range of pro-environmental behavioural determinants (based on the Kollmuss and Agyeman (2002) model of pro-environmental behaviour) and psychological distance. I found that psychological distance was significantly reduced after the VR film, compared to the control group, and this manifested differentially across the components of psychological distance. The participant responses indicated a consistently emotional reaction to the VR film, with sadness, guilt, and connection to nature the dominant themes. Different interpretations and applications of responsibility were also found. This primarily manifested as ‘personal’, ‘shared’, ‘other’ and ‘abstract’ responsibility, with ‘shared’ and ‘other’ being the most common responses. This indicates that for practitioners and researchers utilising environment-themed VR in order to raise awareness, increase knowledge, or change behaviour, there is a limited time period where this opportunity lies to catalyse change. There is potential for VR to play an important role in communicating environment and climate related issues effectively to the individual, however showing solutions and facilitating self-efficacy is necessary to enable change.

6.6 References

Ahn, S.J., Bailenson, J.N. and Park, D. 2014. Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. Computers in Human Behavior. 39, pp.235–245.

Ahn, S.J.G., Bostick, J., Ogle, E., Nowak, K.L., McGillicuddy, K.T. and Bailenson, J.N. 2016. Experiencing Nature: Embodying Animals in Immersive Virtual Environments Increases Inclusion of Nature in Self and Involvement With Nature. Journal of Computer-Mediated Communication. 21(6), pp.399–419.

Bailey, J.O., Bailenson, J.N., Flora, J., Armel, K.C., Voelker, D. and Reeves, B. 2015. The Impact of Vivid Messages on Reducing Energy Consumption Related to Hot Water Use. Environment and Behavior. 47(5), pp.570–592.

Bennett, G. and Canner, L. 2019. Lost city of mer: VR experience In:, pp.25–26. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85076601672&doi=10.1145%2f3355355.3361897&partnerID=40&md5=a1cb36e22f1169fc536453b136a3fbd7.

Bradley, M.M. and Lang, P.J. 1994. Measuring emotion: The self-assessment manikin and the semantic differential. Journal of Behavior Therapy and Experimental Psychiatry. 25(1), pp.49–59.

Breves, P. 2020. Bringing People Closer: The Prosocial Effects of Immersive Media on Users' Attitudes and Behavior. Nonprofit and Voluntary Sector Quarterly. 49(5), pp.1015–1034.

Breves, P. and Heber, V. 2020. Into the Wild: The Effects of 360° Immersive Nature Videos on Feelings of Commitment to the Environment. Environmental Communication. 14(3), pp.332–346.

Breves, P. and Schramm, H. 2021. Bridging psychological distance: The impact of immersive media on distant and proximal environmental issues. Computers in Human Behavior. 115, p.106606.

Buljat, B. 2022. Environmental policy and immersive technologies. Journal of Behavioral Economics for Policy. 6(Special Issue 1), pp.41–47.

Calogiuri, G., Litleskare, S., Fagerheim, K.A., Rydgren, T.L., Brambilla, E. and Thurston, M. 2018. Experiencing Nature through Immersive Virtual

Environments: Environmental Perceptions, Physical Engagement, and Affective Responses during a Simulated Nature Walk. Frontiers in Psychology. 8.

Chester, M., Pincetl, S., Elizabeth, Z., Eisenstein, W. and Matute, J. 2013. Infrastructure and automobile shifts: positioning transit to reduce life-cycle environmental impacts for urban sustainability goals. Environmental Research Letters. 8(1), p.015041.

Chirico, A., Scurati, G.W., Maffi, C., Huang, S., Graziosi, S., Ferrise, F. and Gaggioli, A. 2020. Designing virtual environments for attitudes and behavioral change in plastic consumption: a comparison between concrete and numerical information. Virtual Reality.

Coughlan, A., Ross, E., Nikles, D., De Cesare, E., Tran, C. and Pensini, P. 2022. Nature guided imagery: An intervention to increase connectedness to nature. Journal of Environmental Psychology. 80, p.101759.

Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y. and Seto, K.C. 2016. Beyond Technology: Demand-Side Solutions for Climate Change Mitigation. Annual Review of Environment and Resources. 41(1), pp.173–198.

Fauville, G., Bailenson, J.N. and Queiroz, A.C.M. 2020. Virtual reality as a promising tool to promote climate change awareness In: J. Kim and H. Song, eds. Technology and Health. Elsevier, pp.91–108.

Fonseca, D. and Kraus, M. 2016. A comparison of head-mounted and hand-held displays for 360° videos with focus on attitude and behavior change In: Proceedings of the 20th International Academic Mindtrek Conference [Online]. Tampere Finland: ACM, pp.287–296. [Accessed 28 February 2022]. Available from: https://dl.acm.org/doi/10.1145/2994310.2994334.

Giacomin, J. and Bertola, D. 2012. Human emotional response to energy visualisations. International journal of industrial ergonomics. 42(6), pp.542–552.

Gregg, E.A., Kidd, L.R., Bekessy, S.A., Martin, J.K., Robinson, J.A. and Garrard, G.E. 2022. Ethical considerations for conservation messaging research and practice. People and Nature. 00, pp.1–15.

Howell, R.A. 2011. Lights, camera … action? Altered attitudes and behaviour in response to the climate change film The Age of Stupid. Global Environmental Change. 21(1), pp.177–187.

Hsu, W.-C., Tseng, C.-M. and Kang, S.-C. 2018. Using Exaggerated Feedback in a Virtual Reality Environment to Enhance Behavior Intention of Water-Conservation. Educational technology and society. 21(4, SI), pp.187–203.

Jones, C., Hine, D.W. and Marks, A.D.G. 2017. The Future is Now: Reducing Psychological Distance to Increase Public Engagement with Climate Change. Risk Analysis. 37(2), pp.331–341.

Kaiser, F.G. 1998. A General Measure of Ecological Behavior. Journal of Applied Social Psychology. 28(5), pp.395–422.

Kandaurova, M. and Lee, S.H. 2019. The effects of Virtual Reality (VR) on charitable giving: The role of empathy, guilt, responsibility, and social exclusion. Journal of Business Research. 100, pp.571–580.

Keller, E., Marsh, J.E., Richardson, B.H. and Ball, L.J. 2022. A systematic review of the psychological distance of climate change: Towards the development of an evidence-based construct. Journal of Environmental Psychology. 81, p.101822.

Lacroix, K. 2018. Comparing the relative mitigation potential of individual pro-environmental behaviors. Journal of Cleaner Production. 195, pp.1398–1407.

Lange, F. and Dewitte, S. 2019. Measuring pro-environmental behavior: Review and recommendations. Journal of Environmental Psychology. 63, pp.92–100.

Markowitz, D.M., Laha, R., Perone, B.P., Pea, R.D. and Bailenson, J.N. 2018. Immersive Virtual Reality field trips facilitate learning about climate change. Frontiers in Psychology. 9(NOV).

Mayer, F.S. and Frantz, C.M. 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology. 24(4), pp.503–515.

Meijers, M.H.C., Torfadóttir, R. "Heather," Wonneberger, A., Maslowska, E., 2023. Experiencing Climate Change Virtually: The Effects of Virtual Reality on Climate Change Related Cognitions, Emotions, and Behavior. Environmental Communication 1–21.

Milfont, T.L. 2009. The effects of social desirability on self-reported environmental attitudes and ecological behaviour. The Environmentalist. 29(3), pp.263–269.

O’Neill, S. and Nicholson-Cole, S. 2009. “Fear Won’t Do It”: Promoting Positive Engagement With Climate Change Through Visual and Iconic Representations. Science Communication. 30(3), pp.355–379.

Pallant, J. 2020. SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS 7th ed. Oxon.: Routledge.

Pek, J. and Flora, D.B. 2018. Reporting effect sizes in original psychological research: A discussion and tutorial. Psychological Methods. 23(2), pp.208–225.

Plechatá, A., Morton, T., Perez-Cueto, F.J.A., Makransky, G., 2022. A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change. Sci Rep 12, 14315.

Povey, R., Wellens, B. and Conner, M. 2001. Attitudes towards following meat, vegetarian and vegan diets: an examination of the role of ambivalence. Appetite. 37(1), pp.15–26.

Raja, U.S. and Carrico, A.R. 2021. A Qualitative Exploration of Individual Experiences of Environmental Virtual Reality Through the Lens of Psychological Distance. Environmental Communication. 15(5), pp.594–609.

Shafer, D.M., Carbonara, C.P. and Korpi, M.F. 2019. Factors Affecting Enjoyment of Virtual Reality Games: A Comparison Involving Consumer-Grade Virtual Reality Technology. Games for Health Journal. 8(1), pp.15–23.

Soliman, M., Peetz, J. and Davydenko, M. 2017. The impact of immersive technology on nature relatedness and pro-environmental behavior. Special Issue: New Evidentiary Standards for the Science of Technology and Human Behavior. 29(1), pp.8–17.

Spence, A., Poortinga, W. and Pidgeon, N. 2012. The Psychological Distance of Climate Change. Risk Analysis. 32(6), pp.957–972.

Trope, Y. and Liberman, N. 2010. Construal-Level Theory of Psychological Distance. Psychological review. 117(2), pp.440–463.

Whitburn, J., Linklater, W. and Abrahamse, W. 2019. Meta-analysis of human connection to nature and proenvironmental behavior. Conservation Biology.

Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environmental Research Letters. 12(7), p.074024.

Xie, B., Brewer, M.B., Hayes, B.K., McDonald, R.I. and Newell, B.R. 2019. Predicting climate change risk perception and willingness to act. Journal of Environmental Psychology. 65, p.101331.

Chapter 7 Discussion

This thesis aimed to examine psychological barriers to pro-environmental behaviour, with a focus on virtual reality as a behavioural intervention. This chapter brings together three phases of research which each address the components of this objective. This chapter is structured through a summary of the key findings by research question and the interrelationships across the three phases of work, followed by a discussion of the application of these findings, with recommendations for future research and industry. Chapter 8 then discusses limitations and reflections on research practice and the research process with recommendations for research and researchers.

The first research question asked the overarching question of ‘‘how has virtual reality been used to research pro-environmental behaviour?’ through three sub-questions:

- RQ1: How has virtual reality been found to affect pro-environmental behaviour?
- RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?
- RQ3: How is behavioural theory applied across pro-environmental behavioural change research which utilises virtual reality?

This was examined through a systematic review of the literature in the virtual reality – pro-environmental behaviour space. At the time of data collection (2018-2020), relatively little focus had been given to pro-environmental outcomes after using VR as a behavioural intervention. This systematic review found that the research body was dominated by computer science disciplines exploring technological and experiential elements of virtual reality, as opposed to the behavioural response and outcomes. However, the research that had been conducted focussed on experimental, quantitative work, which was largely explorative due to the nascent nature of the body of research. This manifested particularly in the creation of new behavioural or experiential metrics, as opposed to a focus on using existing metrics to enable buildable research.

The limitations of this existing body of work highlighted several research gaps which were used to shape the second and third phases of this research. The lack of longitudinal work, common across environmental psychology and other

behavioural research (Von Wehrden et al., 2017), was also present in this research body, with most research conducted ‘on the day’ with little evidence of follow up or longitudinal work. A second limitation which was the subject of much of the systematic review discussion, was the around the use of theory, both as a structure in which to test ideas, and as a possible analytical framework for findings. The dearth of research which explicitly referenced theoretical grounding was somewhat mitigated by the implicit use of theory. Theory was implicitly used through the questions asked and the metrics used, which often implied assumptions of the use of the Theory of Planned Behaviour or the Value-Belief-Norm theory. A clear gap in the research body was the lack of consideration of psychological barriers and their role in the theory of behaviour change and as components to measure as outcomes. The third key limitation was the focus on small scale, low impact behaviours, which this work goes on to address.

Due to the presence of these limitations, Phase 2 and 3 of this thesis aimed to directly address these gaps through the explicit use of pre-existing and externally validated metrics, conducting research over a longer timescale, focused on high impact behaviours, and with the explicit measurement and conceptualisation of psychological barriers.

The second phase of the work focused on a deep-dive into psychological barriers, in order to develop insights from wider pro-environmental behavioural change literature. This would then be integrated with the insights from the VR-pro-environmental behaviour research in Phase 1, to examine these two dimensions in conjunction in Phase 3. This was structured under the overarching research question: “What role do psychological barriers play in the pro-environmental behaviour change mechanism?”, although Phase 3 also contributes to this question. Three questions were used to examine this question:

- RQ4: How can psychological barriers to pro-environmental behaviour change affect meat consumption in individuals?
- RQ5: How does psychological distance manifest as a barrier to meat consumption reduction?

- RQ6: How can these psychological barriers be overcome?

A rapid evidence review was used to answer this question, partly due to Covid-19 limitations and uncertainty, but focusing on the case of meat consumption behaviours enabled a specific approach which lends itself to applying a systematic approach (Bianchi et al., 2018; Taufik et al., 2019). The key findings centred on theoretical insights and development around how psychological barriers are conceptualised, measured and how findings translate to policy recommendations. Empirically, this review found consensus among the research on psychological barriers to meat consumption behaviour change, around factors such as the importance of habit and existing behavioural patterns as psychological barriers to change (Rees et al., 2018), which supports research on habits across other pro-environmental behaviours (e.g. Russell and Knoeri (2020), Barr et al. (2005)). The majority of the factors identified as impacting behaviour change could be categorised with the Kollmuss and Agyeman (2002) model (e.g. knowledge, values, emotion), however there were some outliers which did not fit within the model or within the concept of psychological distance. These outliers highlight theoretical or conceptual gaps in the behaviour change mechanism, as the three outliers were; self-efficacy, self-perception of barriers and behaviour, and the gap between perception of 'reducing meat consumption' and 'increasing plant-based diet'. The self-perception of barriers and behaviour is examined in the third phase of this thesis, in order to develop insights on how this manifests within the context of a specific behavioural intervention. From these findings, expanding the conceptualisation of the barriers within the Kollmuss and Agyeman (2002) model as either blocks or gaps is suggested, in order to aid the creation and effectiveness of interventions.

Similarities within the findings from Phase 1 were found. Conceptually, a lack of examination of the effect of psychological distance on meat consumption behaviours explicitly was found, although it could be argued that this was implicitly present within research (e.g. values (Hoek et al., 2017), life events (Kemper, 2020), emotional connection to food (Circus and Robison, 2019)), due to the cognitive dissonance often identified around meat consumption behaviours. From a research process perspective, there were similar challenges with conducting longitudinal research which limits the measurement

of effectiveness over time of behavioural interventions. Additionally, the use of theory was predominantly implied through the research questions asked, methods utilised, and components of behaviour measured, as opposed to through explicit theoretical testing. As with the use of virtual reality for pro-environmental behaviour change, the dominant theoretical paradigms were the Theory of Planned Behaviour (Ajzen, 1991) and the 'value-belief-norm' theory (Stern et al., 1999), with some additional food and appetite specific theories utilised (e.g. the Health Belief Model (Urbanovich and Bevan, 2020)).

Phase 3 sought to address some of these limitations. This was structured under the overarching research question 'Can psychological barriers to pro-environmental behaviour change be overcome through VR?'. This is addressed through an experimental design which explored the pro-environmental behavioural and experiential impact of a climate-themed VR experience. The experiment built on Phase 1 and 2 by exploring meat consumption as a behavioural outcome and the impact of psychological distance as a specific barrier to change. These concepts were examined through two research questions:

- RQ7: What are the effects of an environmental VR intervention over time on behavioural determinants and outcomes?
- RQ8: What are the effects of an environmental VR intervention on psychological distance?

The experimental results found that psychological distance was reduced after seeing the VR intervention. The quantitative findings paint a complex picture across the behavioural determinants and outcomes, where the majority of the statistically significant findings were present in the control group over time (T1 to T3) which may indicate measurement errors or biases present. This measurement of trends without statistical significance is common in psychological and behavioural research, however publication bias often results in only a narrow band of research entering public domain through peer-review (Lange and Brick, 2021). However, despite the lack of statistically significant findings, the qualitative data added nuance, context and a challenge to the quantitative findings. The qualitative data found deep (and common) emotional responses to the experience, with clear notions and themes of responsibility, as

well as guilt, sadness and empathy. The theme of responsibility aligns with the experience of psychological distance, as the most common reference to responsibility was as ‘other’ or ‘abstract’ responsibility to address the environmental and ethical issues referenced in the VR experience.

These findings tell us about how effective VR is as a behavioural intervention to encourage pro-environmental behaviour. The decay rate from post-test to ‘3 weeks later’ (time 2 to time 3) indicates the need for repeated interventions in order to mitigate this and maintain any positive change that may have occurred after a VR experience.

7.1 The role of psychological barriers

This research has examined the role of psychological barriers in the pro-environmental behaviour change mechanism, through the use of virtual reality as a de facto behavioural intervention to encourage pro-environmental behaviour change.

7.1.1 Theoretical critique

The systematic review identified the lack of explicit behavioural theory applied to research in the VR – pro-environmental behavioural space, and the common implicit application of the Theory of Planned Behaviour and the value-belief-norm theory. This limitations associated with the use of a narrow band of theoretical framings is reflective of historical trends in pro-environmental behavioural research, in addition to the dominance of self-reported measures (Lange, 2022). Focusing and measuring a narrow selection of behavioural determinants (and/or outcomes) presents limitations around external validity and extrapolation beyond the specific research setting.

The systematic review found that pro-environmental behaviour was conceptualised in a narrow way within this specific research area of VR and pro-environmental behaviour. This may be explained by the disciplines and paradigms held by the researchers in this space (primarily studies on technical components of VR, or psychologists exploring experiential impact of VR). The dominance of these theoretical paradigms limit application to different contexts. Theory can be utilised to increase the effectiveness of VR interventions by

providing a framework to test or to explain individual behavioural response to a VR experience. To move beyond the dominant theoretical paradigms, applying a holistic understanding of pro-environmental behavioural mechanisms and factors can increase the effectiveness of interventions (Klöckner, 2013). In this case, a 'holistic understanding' refers to considering behavioural factors beyond the well-studied environmental knowledge, values, attitudes, and social norms, as well as conceptualising behaviour as a non-linear, dynamic process, as Kollmuss and Agyeman (2002) do.

One component of this gap in the use of behavioural theory is the consideration of psychological barriers. One of the assumptions around the expansion and proliferation of VR as a communication tool for environmental and campaigning organisations is around its value as a tool to bring distant experiences closer to the individual. Therefore, there is a disconnect between the intention of the tool and the theories used to support the design of experiences. Chapter 5 identified the importance of a range of psychological barriers within the context of meat consumption behaviours. The insights from this could be applied to other behavioural domains and other intervention evaluations.

7.1.2 Psychological barriers

Psychological barriers were the central concept within this research, as it is the thread that brings together the three phases of work. The inclusion, or more commonly exclusion, of psychological barriers from dominant theoretical paradigms was identified in the first phase of the work around virtual reality and pro-environmental behaviour change.

Within Phase 2, based on the rapid evidence review on psychological barriers to meat consumption reduction, it was suggested that a conceptualisation of psychological barriers could be as either blocks or gaps in the behavioural mechanism. This refers to processes within the behavioural mechanism where barriers manifest as active, hard 'blocks' on behaviour change (e.g. emotional connection to meat preventing reduction in meat consumption), or as 'gaps which refer to an absence of a required behavioural determinant (e.g. lack of understanding relative impacts of different pro-environmental behaviours). This notion of gaps was also found within the systematic review on VR as a pro-

environmental behavioural intervention, as within this research body, four studies explore psychological barriers implicitly, with Ahn et al. (2016) exploring temporal distance explicitly. However, notions of psychological gaps within the behavioural mechanism were more widely recognised, and often identified as possible explanations for empirical findings. Psychological gaps were found, with Soliman et al. (2017, p.15) finding that "*watching the video depicting the natural environment did not meaningfully change the number of environmental choices that participants made, despite its effect on attitudes toward nature. This suggests a possible attitude–behavior gap*". This attitude-behaviour gap has been found across pro-environmental behaviour research (Wienrich et al., 2021), where psychological barriers have been found to moderate this gap across context-specific behavioural domains (Vieira et al., 2023).

The presence of psychological distance has been found to act as a gap within the behavioural mechanism which prevents behaviour change (Chu, 2022; Duke and Holt, 2022). Psychological distance can be bridged through using 'local' imagery which can increase relatedness to the individual (Nicholson-Cole, 2005), however, whether this translates to behaviour is still unclear. The testing and exploration of psychological barriers manifesting as blocks or gaps within the behavioural mechanism could be an avenue for future research. The mechanics of psychological distance are explored in Keller et al.'s (2022) excellent systematic review of the psychological distance literature. They recommend a reconceptualisation of psychological distance, with a key recommendation being an exploration of the gap between behaviour and outcome. They allude to similar findings as in Chapter 5, where a gap between the perception of distance and actual distance was identified.

7.1.3 Overcoming psychological barriers

Virtual reality is utilised by a range of campaigning and advocacy organisations, within and beyond the environmental space. Often, a key theme or subject of the VR content is 'nature' or exotic, far-flung locations, often with charismatic megafauna, which are used across climate communication to create awe and empathy (Wang et al., 2018; Born, 2019).

The systematic review found that with the exception of a driving behaviour study, all studies utilised nature as the main theme of the VR content, despite the framing of the experiment and research questions varying. Nature was used through the environment being ‘exotic’ or ‘wild’, or through highlighting the impact of behaviours within the virtual environment on nature. Within the research body examined in the systematic review, the environmental issues studied included: climate change (Ballantyne et al., 2016; Nim et al., 2016; Cepok et al., 2019; Nelson et al., 2020; Petersen et al., 2020), connection to nature (Ahn et al., 2016; Soliman et al., 2017; Calogiuri et al., 2018), resource use (Bailey et al., 2015; Ahn et al., 2016; Chirico et al., 2020), deforestation (Ahn et al., 2016; Breves, 2020), marine pollution (Calvi et al., 2017; Markowitz et al., 2018), fertiliser impact (Fan et al., 2010) and water conservation (Hsu et al., 2018); which highlights the breadth of application of nature as a key theme.

The use of nature and wilderness in the content used for Phase 3 emerged as key themes from the qualitative data, where participants identified nature as a key message within the VR content (e.g. protecting nature). It is worth exploring the implications from these findings due to the overwhelming dominance of nature-based VR experiences and content, within environmental communications and more broadly (on VR streaming platforms, for instance). One of the key assumptions of VR is that it can ‘bridge the gap’ between the individual experiencing the content, and the issue/place/person in the content (Buljat, 2022; Attanasi et al., 2023; Larreina-Morales and Gunella, 2023). This research has examined this assumption through the lens of psychological distance. However, connection to nature is an interesting behavioural factor to examine due to this market dominance. This research found that connection to nature followed the same pattern as most of the other metrics, where it increased (became more pro-environmental) immediately post-test, and then returned to pre-test levels after 3 weeks.

An interesting relationship which emerged in this data is the relationship between connection to nature and the sense of responsibility which emerged in Chapter 6. This could be explored through the concept of ‘psychological ownership’. Psychological ownership relates to psychological distance in the sense that the closer the place or thing is to an individual, the more likely they are to take responsibility for it (Wang et al., 2022; Wang et al., 2023). Chapter 6

found a disconnect between the highly emotional qualitative responses to the VR experience, and the references to responsibility which emerged from the perceived messaging within the VR. Individual responsibility was only referenced by a small minority of participants, with the dominant themes being abstract or other responsibility for the environmental issues presented in the VR. An explanation could be related to Schultz's (2000) structure for environmental concerns, where ‘egoist’ and ‘altruistic’ motives produced helping behaviour (within the context of seeing animals harmed in nature). Understanding the underlying value structures of participants or audiences of VR content could enable more effective behavioural interventions to be designed to facilitate greater pro-environmental behaviour change.

The experiment found an increase in the connection with nature scores in the immediate post-test, which corroborates other research in this space. For instance, Breves and Heber (2020) found that immersive nature experiences elicited increased feelings of connection to nature than regular nature videos. Duke and Holt (2022) identified personal experiences through VR as a bridging factor between connection to nature and the psychological distance of climate change felt. However, these findings are highly context-specific as Ahn et al. (2016) found that VR can help overcome the paradox where if individuals feel a sense of responsibility for an issue, they are more likely to feel the issue is not serious. Soliman et al. (2017) also found that using a VR experience did not significantly increase the degree of nature connectedness felt. The complexity identified around psychological distance and connection to nature present some challenges to the conventional wisdom around the use of nature and wilderness in VR as a tool for awe.

The findings in relation to connection to nature provide insights into the broader role of emotion in overcoming psychological barriers to pro-environmental behaviour change. As VR is lauded as being “the empathy machine “ (Milk, 2015), and the systematic review identified that experiential factors such as emotional response after viewing VR content were a key theme in the research body. However, there is potential to examine this further in relation to the implications for behavioural change. An interesting avenue for future research is the relationship between empathy and perspective taking in VR, as in Herrera et

al. (2018), who found that higher perspective taking corresponded to greater pro-social behaviours.

Chapter 5 identified emotion as a key component of psychological barriers to reducing meat consumption. The enjoyment of eating meat and the cultural significance, along with other value-based emotional connections to meat (e.g. Loughnan et al. (2014)), were found to be psychological barriers blocking behaviour change.

The use of emotional messaging and framing to overcome other pro-environmental behaviours was explored in Chapter 6. The VR content viewed had multiple sustainability-related themes and messages, where the participants identified their own perception of the messaging. A conflict arose between the quantitative and qualitative findings, where the Self-Assessment Manikin (SAM) found 40% of participants felt 'neutral' after viewing the VR film. However, the qualitative data showed an overwhelmingly emotive response from the participants, with key themes including sadness and guilt. This could be somewhat explained by the multiple different emotions represented within the qualitative data, that were not able to be articulated through the SAM scale, indicating a need for measuring emotions discretely and in more depth individually (Russell and Ashkanasy, 2021).

Using emotional framing for climate and sustainability messaging has been found to be effective at changing 'hearts and minds' across multiple media, however more work is needed to explore the long-term impact on pro-environmental behaviour change.

7.2 Summary of contributions

The three common research objectives within environmental psychology identified by Lange and Dewitte (2019) are 1) characterising individual behavioural differences, 2) exploring behavioural mechanisms, and 3) evaluating interventions. This research straddles two of the three, as it aims to explore mechanisms of behaviour change through evaluating the effectiveness of VR as an intervention. This work has been guided by critiques of dominant paradigms within behavioural science (e.g. Lange et al. (2021), Nielsen et al. (2021), van Valkengoed et al. (2022)), especially with regard to how knowledge

is generated and built, as well as critiques of how dominant policy paradigms limit the broader application of research (e.g. Shove, 2010).

7.2.1 Theoretical contributions

The key conceptual and theoretical contribution of this thesis centres on the role and importance of psychological barriers within the behaviour change mechanism, within the case of VR as an intervention, and more broadly. This research highlights the importance of psychological barriers at preventing positive behavioural change across a range of pro-environmental outcomes. This research identifies psychological distance as a useful concept to categorise barriers to behaviour change, which complemented the a priori codes derived from the Kollmuss and Agyeman (2002) model, within the context of meat consumption reduction. The empirical findings in chapter 6 found a statistically significant reduction in psychological distance in the VR condition after viewing the VR intervention, while other behavioural factors were not statistically significantly different over time or compared to the control condition. This indicates that psychological distance is a concept worth further research within the context of climate-related VR and communication and intervention mechanisms more broadly.

This work centres and critiques the use of theory as an analytical framework and a useful tool to aid research design and testing. With regards to the recent debate regarding ‘theory vs. impact’ (Lange et al., 2021; Nielsen et al., 2021; van Valkengoed et al., 2021), this research aligns with the final reply to the debate in the Journal of Environmental Psychology exchange (2021) where authors agree that theory is needed (especially within the discussion on constructing effective interventions, and building knowledge) but also that the research should focus on high impact outcomes. The focus within this thesis on high-impact behaviours contributes to this recent, and growing, emphasis on key (sometimes called ‘catalyst’) behaviours. This thesis found that participants responded negatively to the VR intervention in relation to meat consumption (the high-impact behaviour measured). Pro-environmental attitudes to meat consumption and behavioural intention declined after viewing the VR, which

presents interesting insights for both the development of VR interventions, and for how we conceptualise and understand key high-impact behaviours.

A significant portion of this thesis involves a critique of dominant theoretical paradigms often utilised, explicitly or implicitly, in policy, practice and research (as identified within both the systematic review of the VR-pro-environmental behaviour research body, and the rapid evidence review of meat consumption behaviours). This critique centred on the measurement of a narrow band of behavioural determinants and outcomes, with the exclusion of psychological barriers. The Kollmuss and Agyeman (2002) model used proved effective as a model to measure a range of dynamic behavioural determinants and outcomes, and crucially, barriers. A component which requires more investigation with strong theoretical grounding, is the impact of time and potentially decay effects of behavioural outcomes. There were clear trends over time (Chapter 6), where most factors showed a pro-environmental change at post-test (time 2), only to return to pre-test levels after three weeks. This indicates the need for greater consideration of decay rates across behavioural determinants and outcomes, and highlights the need for inclusion within behavioural theoretical frameworks. Similarly, this research shows that concepts such as spillover, the rebound effect and co-benefits need greater theoretical exploration, as these concepts could significantly affect the impact of any given intervention.

7.2.2 Methodological contributions

A key methodological development of this work centres on the systematic review methods themselves, and the development of a set of core principles and methodology for systematic reviews within environmental social sciences. Due to systematic reviews being dominated by use in medical and health research, methodological development was required to ensure systematic reviews were suitable and useful to this research area. Systematic reviews are not unheard of in environmental social science research (the Collaboration for Environmental Evidence Synthesis Assessment Tool (CEESAT) was launched in 2014 (Woodcock et al., 2014)), however there is a degree of variation in the rigour and critical assessment applied. Therefore Chapter 3 and 4 presents a novel approach to systematic reviews within environmental social sciences, with

Chapter 5 presenting a streamlined version which suits responding to a policy need. The key critiques and methodological development centre on the protocol and framework devised which lend itself to applying the systematic review method to contexts beyond quantitative and/or intervention-based research questions, e.g. interdisciplinary bodies of work, mixed-methods or qualitative research bodies, and research questions not examining the effect of a specific intervention. This new framework ensures comprehensiveness of research question design, literature searching, sifting and data extraction, and therefore confidence in the literature selected. This process also developed a set of key points which systematic reviews for environmental social science should adhere to (see Chapter 3.2.2). I argue that systematic reviews are too rigid in their current form, which precludes otherwise suitable questions and research areas being examined in this rigorous way due to methods developed in health disciplines. Therefore, the framework I developed applies the key principles and a more flexible approach in order to enable environmental social science questions to be explored in this rigorous way. These critiques and principles developed supports existing work Haddaway et al. (2015) conducted within the context of conservation biology where principles were developed to increase rigour where a ‘full’ systematic review was unfeasible. These principles address critiques identified through a review of systematic review methodologies which corroborate O’Leary et al.'s (2016) recommendations for increasing the reliability of systematic reviews within environmental social science.

Secondly, the systematic review on VR and pro-environmental behaviour identified that there was consistency in the research designs used to explore these research questions, namely through experimental and quasi-experimental designs. However, a critique of this is the lack of space given to qualitative or mixed methods approaches. Therefore Chapter 6 illustrates the use of a mixed methods approach within an experimental design, where the qualitative findings were some of the most interesting and consistent findings. The methods applied synthesised approaches from sustainability, psychology and social sciences, which is a novel approach in the virtual reality literature.

7.2.3 Empirical contributions

Across the thesis, a key aim was to test the assumptions around the use of VR to overcome psychological distance of climate change and environmental issues. The systematic review (Chapter 4) generated new insights into the research landscape; what behavioural factors were being measured and how in the context of environmental-themed virtual reality interventions. This determined that there has been a dearth of work around psychological barriers to behaviour change using VR, despite the assumptions around its usefulness for encouraging attitudinal and behavioural change. The rapid evidence review (Chapter 5) explored the role of psychological barriers more deeply through the example of meat consumption and found that psychological barriers impacted pro-environmental behaviour change outcomes through a variety of context-specific mechanisms. The rapid evidence review found that psychological distance was a useful structure in which to categorise psychological barriers to reducing meat consumption and highlighted the importance of considering psychological barriers to pro-environmental behaviour change. These empirical findings were brought together and fed into the research design of Phase 3 in terms of the conceptualisation and use of psychological barriers (and how they were measured).

Phase 3 (Chapter 6) provided empirical contributions on the impact of an environmental-themed VR experience on a range of behavioural determinants, barriers, and outcomes. The key contribution is in relation to the statistically significant findings on the impact of the VR intervention of psychological distance, and complement recent work on the importance of psychological distance (e.g. Duke and Holt (2022), Keller et al. (2022)). This supports industry assumptions around the effectiveness of VR to bring distance places, people and issues closer to the individual, however, the impact on subsequent behavioural factors (e.g. knowledge, attitudes) and resultant behaviour is still unclear and warrants further research, especially over time. The non-statistically significant results also provide new insights, with complexity found in the non-significant and sometimes contradictory findings. The complexity around the impact of the VR intervention on attitudes to meat consumption is particularly noteworthy due to the contradiction between this and the previous evidence showing a positive impact of VR on environmental attitudes (Wang et al., 2021).

The findings support the need to measure longitudinally to explore the impact of interventions over time and the persistence effect, as well as the need for interventions to be repeated to increase the longevity of impact. The complexity in the findings highlights the need to consider behaviour holistically to understand the impact of interventions more fully, by measuring a range of determinants, barriers and outcomes.

7.3 References

Ahn, S.J.G., Bostick, J., Ogle, E., Nowak, K.L., McGillicuddy, K.T. and Bailenson, J.N. 2016. Experiencing Nature: Embodying Animals in Immersive Virtual Environments Increases Inclusion of Nature in Self and Involvement With Nature. Journal of Computer-Mediated Communication. 21(6), pp.399–419.

Ajzen, I. 1991. The Theory of Planned Behavior In: Organizational Behavior and Human Decision Processes., pp.179–211.

Attanasi, G., Buljat Raymond, B., Festré, A. and Guido, A. 2023. Reducing the Psychological Distance of Plastic Pollution: How Convincing is Augmented Reality?

Barr, S., Gilg, A.W. and Ford, N. 2005. The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. Energy Policy. 33(11), pp.1425–1444.

Bailey, J.O., Bailenson, J.N., Flora, J., Armel, K.C., Voelker, D. and Reeves, B. 2015. The Impact of Vivid Messages on Reducing Energy Consumption Related to Hot Water Use. Environment and Behavior. 47(5), pp.570–592.

Ballantyne, A.G., Wibeck, V. and Neset, T.-S. 2016. Images of climate change – a pilot study of young people's perceptions of ICT-based climate visualization. Climatic Change. 134(1–2), pp.73–85.

Bianchi, F., Dorsel, C., Garnett, E., Aveyard, P. and Jebb, S.A. 2018. Interventions targeting conscious determinants of human behaviour to reduce the demand for meat: a systematic review with qualitative comparative analysis. International Journal of Behavioral Nutrition and Physical Activity. 15.

Born, D. 2019. Bearing Witness? Polar Bears as Icons for Climate Change Communication in National Geographic. Environmental Communication. 13(5), pp.649–663.

Breves, P. 2020. Bringing People Closer: The Prosocial Effects of Immersive Media on Users' Attitudes and Behavior. Nonprofit and Voluntary Sector Quarterly. 49(5), pp.1015–1034.

Breves, P. and Heber, V. 2020. Into the Wild: The Effects of 360° Immersive Nature Videos on Feelings of Commitment to the Environment. Environmental Communication. 14(3), pp.332–346.

Buljat, B. 2022. Environmental policy and immersive technologies. Journal of Behavioral Economics for Policy. 6(Special Issue 1), pp.41–47.

Calogiuri, G., Litleskare, S., Fagerheim, K.A., Rydgren, T.L., Brambilla, E. and Thurston, M. 2018. Experiencing Nature through Immersive Virtual Environments: Environmental Perceptions, Physical Engagement, and Affective Responses during a Simulated Nature Walk. Frontiers in Psychology. 8.

Calvi, L., Santos, C.P., Relouw, J., Endrovski, B., Rothwell, C., Sara, A., Lucrezi, S., Palma, M. and Pantaleo, U. 2017. A VR Game to Teach Underwater Sustainability while Diving In: 2017 Fifth IFIP Conference on Sustainable Internet and ICT for Sustainability. Sustainable Internet and ICT for Sustainability. New York: IEEE, pp.114–117.

Cepok, J., Arzaroli, R., Marnholz, K., Grobe, C.S., Reuter, H., Nelson, K., Lorenz, M., Weller, R. and Zachmann, G. 2019. Effects of VR on intentions to change environmental behavior In:, pp.874–875. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071861024&doi=10.1109%2fVR.2019.8797849&partnerID=40&md5=c3661ce52605a307f474e92de8edd044.

Chirico, A., Scurati, G.W., Maffi, C., Huang, S., Graziosi, S., Ferrise, F. and Gaggioli, A. 2020. Designing virtual environments for attitudes and behavioral change in plastic consumption: a comparison between concrete and numerical information. Virtual Reality.

Chu, H. 2022. Construing Climate Change: Psychological Distance, Individual Difference, and Construal Level of Climate Change. Environmental Communication. 0(0), pp.1–17.

Circus, V.E. and Robison, R. 2019. Exploring perceptions of sustainable proteins and meat attachment. BRITISH FOOD JOURNAL. 121(2), pp.533–545.

Duke, J.R. and Holt, E.A. 2022. Seeing climate change: psychological distance and connection to nature. Environmental Education Research. 28(7), pp.949–969.

Fan, S., Zhang, Y., Fan, J., He, Z. and Chen, Y. 2010. The application of virtual reality in environmental education: Model design and course construction *In*: *2010 International Conference on Biomedical Engineering and Computer Science, ICBECS 2010* [Online]. IEEE.

Haddaway, N.R., Woodcock, P., Macura, B. and Collins, A. 2015. Making literature reviews more reliable through application of lessons from systematic reviews: Making Literature Reviews More Reliable. Conservation Biology. 29(6), pp.1596–1605.

Herrera, F., Bailenson, J., Weisz, E., Ogle, E. and Zaki, J. 2018. Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. PLOS ONE. 13(10), p.e0204494.

Hoek, A.C., Pearson, D., James, S.W., Lawrence, M.A. and Friel, S. 2017. Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours. Appetite. 108, pp.117–131.

Hsu, W.-C., Tseng, C.-M. and Kang, S.-C. 2018. Using exaggerated feedback in a virtual reality environment to enhance behavior intention of water-conservation. Journal of Educational Technology & Society. 21(4), pp.187–203.

Keller, E., Marsh, J.E., Richardson, B.H. and Ball, L.J. 2022. A systematic review of the psychological distance of climate change: Towards the development of an evidence-based construct. Journal of Environmental Psychology. 81, p.101822.

Kemper, J.A. 2020. Motivations, barriers, and strategies for meat reduction at different family lifecycle stages. Appetite. 150.

Klöckner, C.A. 2013. A comprehensive model of the psychology of environmental behaviour—A meta-analysis. Global Environmental Change. 23(5), pp.1028–1038.

Kollmuss, A. and Agyeman, J. 2002. Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research. 8(3), pp.239–260.

Lange, F. 2022. Behavioral paradigms for studying pro-environmental behavior: A systematic review. Behavior Research Methods.

Lange, F. and Brick, C. 2021. Changing Pro-Environmental Behavior: Evidence from (Un)Successful Intervention Studies. Sustainability. 13(14), p.7748.

Lange, F., Nielsen, K.S., Cologna, V., Brick, C. and Stern, P.C. 2021. Making theory useful for understanding high-impact behavior. A response to van Valkengoed et al. (2021). Journal of Environmental Psychology. 75.

Larreina-Morales, M.E. and Gunella, C. 2023. Video games for environmental awareness: the accessibility gap. Universal Access in the Information Society.

Loughnan, S., Bastian, B. and Haslam, N. 2014. The Psychology of Eating Animals. Current Directions in Psychological Science. 23(2), pp.104–108.

Markowitz, D.M., Laha, R., Perone, B.P., Pea, R.D. and Bailenson, J.N. 2018. Immersive Virtual Reality field trips facilitate learning about climate change. Frontiers in Psychology. 9(NOV).Milk, C. (2015). How virtual reality can create the ultimate empathy machine [video file]. https://www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_ empathy_machine/transcript

Nelson, K.M., Anggraini, E. and Schlüter, A. 2020. Virtual reality as a tool for environmental conservation and fundraising. Plos one. 15(4), p.e0223631.

Nicholson-Cole, S.A. 2005. Representing climate change futures: a critique on the use of images for visual communication. Computers, Environment and Urban Systems. 29(3), pp.255–273.

Nielsen, K.S., Cologna, V., Lange, F., Brick, C. and Stern, P.C. 2021. The case for impact-focused environmental psychology. Journal of Environmental Psychology. 74, p.101559.

Nim, H.T., Wang, M., Zhu, Y., Sommer, B., Schreiber, F., Boyd, S.E. and Wang, S.J. 2016. Communicating the effect of human behaviour on the great barrier reef via mixed reality visualisation In: Big Data Visual Analytics (BDVA), 2016. IEEE, pp.1–6.

O'Leary, B.C., Kvist, K., Bayliss, H.R., Derroire, G., Healey, J.R., Hughes, K., Kleinschroth, F., Sciberras, M., Woodcock, P. and Pullin, A.S. 2016. The

reliability of evidence review methodology in environmental science and conservation. Environmental Science & Policy. 64, pp.75–82.

Petersen, G.B., Klingenberg, S., Mayer, R.E. and Makransky, G. 2020. The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. British Journal of Educational Technology. 51(6), pp.2098–2114.

Rees, J.H., Bamberg, S., Jaeger, A., Victor, L., Bergmeyer, M. and Friese, M. 2018. Breaking the Habit: On the Highly Habitualized Nature of Meat Consumption and Implementation Intentions as One Effective Way of Reducing It. Basic and Applied Social Psychology. 40(3), pp.136–147.

Russell, S.V. and Knoeri, C. 2020. Exploring the psychosocial and behavioural determinants of household water conservation and intention. International Journal of Water Resources Development. 36(6), pp.940–955.

Russell, S.V. and Ashkanasy, N.M. 2021. Pulling on Heartstrings: Three Studies of the Effectiveness of Emotionally Framed Communication to Encourage Workplace Pro-Environmental Behavior. Sustainability. 13(18), p.10161.

Schultz, P.W. 2000. Empathizing With Nature: The Effects of Perspective Taking on Concern for Environmental Issues. Journal of Social Issues. 56(3), pp.391–406.

Shove, E. 2010. Beyond the ABC: Climate Change Policy and Theories of Social Change. Environment and Planning A: Economy and Space. 42(6), pp.1273–1285.

Soliman, M., Peetz, J. and Davydenko, M. 2017. The impact of immersive technology on nature relatedness and pro-environmental behavior. Special Issue: New Evidentiary Standards for the Science of Technology and Human Behavior. 29(1), pp.8–17.

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A. and Kalof, L. 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review. 6(2), p.17.

Taufik, D., Verain, M.C.D., Bouwman, E.P. and Reinders, M.J. 2019. Determinants of real-life behavioural interventions to stimulate more plant-

based and less animal-based diets: A systematic review. Trends in Food Science & Technology. 93, pp.281–303.

Urbanovich, T. and Bevan, J.L. 2020. Promoting Environmental Behaviors: Applying the Health Belief Model to Diet Change. Environmental Communication. 0(0), pp.1–15.

van Valkengoed, A.M., Abrahamse, W. and Steg, L. 2022. To select effective interventions for pro-environmental behaviour change, we need to consider determinants of behaviour. Nature Human Behaviour. 6(11), pp.1482–1492.

van Valkengoed, A.M., Steg, L., Perlaviciute, G., Schultz, P.W., Brosch, T., Gatersleben, B., Nordlund, A., Pahl, S. and Whitmarsh, L. 2021. Theory enhances impact. Reply to: 'The case for impact-focused environmental psychology'. Journal of Environmental Psychology. 75, p.101597.

Vieira, J., Castro, S.L. and Souza, A.S. 2023. Psychological barriers moderate the attitude-behavior gap for climate change J. A. García, ed. PLOS ONE. 18(7), p.e0287404.

Von Wehrden, H., Luederitz, C., Leventon, J. and Russell, S. 2017. Methodological Challenges in Sustainability Science: A Call for Method Plurality, Procedural Rigor and Longitudinal Research. Challenges in Sustainability. 5(1).

Wang, S., Corner, A., Chapman, D. and Markowitz, E. 2018. Public engagement with climate imagery in a changing digital landscape. Wiley Interdisciplinary Reviews: Climate Change. 9(2), p.e509.

Wang, K., Tekler, Z.D., Cheah, L., Herremans, D. and Blessing, L. 2021. Evaluating the Effectiveness of an Augmented Reality Game Promoting Environmental Action. *Sustainability*. **13**(24), p.13912.

Wang, X., Fielding, K.S. and Dean, A.J. 2023. "Nature is mine/ours": Measuring individual and collective psychological ownership of nature. Journal of Environmental Psychology. 85, p.101919.

Wang, X., Fielding, K.S. and Dean, A.J. 2022. Psychological ownership of nature: A conceptual elaboration and research agenda. Biological Conservation. 267, p.109477.

Wienrich, C., Döllinger, N. and Hein, R. 2021. Behavioral Framework of Immersive Technologies (BehaveFIT): How and Why Virtual Reality can Support Behavioral Change Processes. Frontiers in Virtual Reality. 2.

Woodcock, P., Pullin, A.S. and Kaiser, M.J. 2014. Evaluating and improving the reliability of evidence syntheses in conservation and environmental science: A methodology. Biological Conservation. 176, pp.54–62.

Chapter 8 Reflections

8.1 Challenges in using virtual reality

Throughout this research process, I have reflected on how VR is used as a research subject and a research tool. These topics will be explored here, with some suggestions for how to use VR going forward. Virtual Reality is increasingly recognised as a useful tool for research and practitioners to bring otherwise distant, or logistically challenging experiences (sights, sounds, feelings) closer to an individual. It is an exciting tool, and with technological developments to the realism and quality of the experience, as well as the increasing variety and depth of experiences available, consideration needs to be given to how we as researchers are utilising this tool.

8.1.1 Ethics

The systematic review highlighted some ethical issues through the structure of the critical appraisal, as well as wider literature which utilised VR as a research tool and subject. This included baseline best practice expectations not being met, such as reference to ethical approval not being made within research outputs, an inconsistent approach to what information participants were given to help them decide whether to take part in the research. These basic requirements (for instance those identified within the Rees et al. (2009) critical appraisal assessments for systematic reviews), should be included as standard in all experimental VR research outputs. These include confirming ethical approval was granted for the research, detailing participant recruitment and information provided, and a broad outline of any risks to participants.

The critical appraisal identified a lack of risk-of-bias analysis and other positionality-related concerns spread widely across the included studies. Acknowledgement of researcher positionality can increase the transparency of the research and research process (Siegel et al., 2021), and with pro-environmental behavioural research which utilises VR being an increasingly interdisciplinary field, the role of positionality and reflexivity is key.

Several studies utilised a VR intervention which was intended to elicit an emotional response, and indeed measured this. Emotion is a well-established

tool to encourage pro-environmental empathy (Berenguer, 2007), however the ethical considerations associated with emotion could be integrated more thoroughly and explicitly into the intervention design. As interventions often involve a sense of 'persuasion' in order to examine the behavioural impact, ethical concerns are raised when emotions are intentionally manipulated within research (Sheppard, 2005). Ethical issues around emotion and pro-environmental behaviour research should include consideration of responses including eco-anxiety, which could be mitigated by considering the duty of care to the participants, which extends beyond the time in the laboratory/experiment. The intervention and research experience could be considered to begin from first contact, as opposed to the start of the data collection process. Similarly, a greater duty of care for our research participants could help mitigate emotions we may well have had a role in causing through our research, for instance, apathy or feeling a lack of agency around environmental and climate issues. As researchers working to mitigate and adapt to environmental issues, we have a duty of care to not exacerbate these issues for our participants (ethically, and also considering the potential environmental impact).

Ethical considerations go beyond physical health and safety considerations, especially if using emotive content, and do not end when participants leave the laboratory or virtual environment.

8.2 Methodological reflections

One suggestion which could address some methodological and empirical limitations (e.g. dominance of a narrow set of theoretical and measurement paradigms), could be to reconsider the boundaries of a VR experience and experiment. For instance, within an experimental or quasi-experiment design (which much of the VR research utilises (McCall and Blascovich, 2009)), data tends to be collected in a pre-post test design, or only post-test. If this was broadened to include considering the VR experience from first point of contact, potentially through observational methods, it could increase the contextualisation of findings. Capturing the nuanced understand of the participants' own research experience could enhance our understanding of behaviour.

The issue of external validity was identified in Chapter 4, as a research challenge common to behavioural work. Psychological and behavioural research often occurs within labs in universities, as well as 'in the field' to enable increased external validity. The research experience of participants within VR research often focuses on the virtual experience and the participants' response to that content. However, broadening out the experience and subsequent data collection could help increase our understanding of how people engage with VR and help contextualise their experiences and therefore the data collected. Observational data is under-utilised, especially within behavioural research, and there is an opportunity with the expansion of VR as a research tool, to expand the use of observational methods to complement experimental methods. Considering the research experience from the moment the participant is engaged, as opposed to when they put on the VR headset is essential to maximise the usefulness of observational methods. This would increase the external validity of the data if triangulated with pre-post test data, by offering context for emotional response, engagement with content, presence and immersion, for example.

Research logistics means that we often can only feasibly capture a narrow array of behavioural components. The research examined in the systematic review mirrors broader research in social psychology, where measuring behaviour outside the laboratory, or over time, is logistically challenging and creates a tension between experimental control and ecological validity (Gillath et al., 2008). Ecological validity refers to the relevance of research to 'real life' and "*everyday functionin*g" (Parsons, 2015, p.2).

However, if we move towards mixed methods designs, including observational or reflexive work, we could better contextualise the quantitative data. The inclusion of qualitative, open questions in the experiment within Chapter 6 enabled a sequential analysis that increased the depth and meaning of the data set. The systematic review found that the dominance of using VR in laboratory conditions limits ecological validity and generalisability, despite increased ecological validity being a key advantage for the use of VR in research (Gillath et al., 2008). Utilising virtual reality has been found to overcome existing methodological issues in behavioural psychology and improve "*experimental control, reproducibility, and ecological validity*" (Pan and Hamilton, 2018, p395).

Therefore, by integrating data collection approaches which include observational, reflexive or other qualitative elements within research designs, this can mitigate the limitations of lab-based VR studies.

8.2.1 Buildable knowledge and consistent metrics

A key (and common) critique of the research bodies examined in Chapter 4 and 5 was identified as the way in which knowledge was built in this emerging area of research, and how it was conducted. Chapter 4 identified a number of gaps or areas for future research. Firstly, behaviour is conceptualised in a fairly narrow sense, and expanding this, with the help and application of theory, could help build the evidence base up in a more systematic way. Secondly, the concepts chosen to be examined, and the respective use of metrics could focus on building knowledge though consistent application of metrics, which move away from a 'pick and choose' approach found within behavioural research. Metrics should be applied to build and expand the application and ecological validity. Thirdly, a range of logistical challenges using VR in research highlight some issues within research designs, such as a lack of longitudinal work preventing the effectiveness of interventions being fully evaluated.

These trends are understandable due to the novelty of the use of VR as a tool for, and subject of, research. Findings from methodological insights and critique from Chapter 5 can be used to develop the methodologies associated with the use of VR as a tool for measuring and exploring behavioural research.

8.3 Personal reflections on my role in the research process

It is important to note that the perspective of the researcher significantly impacts the results, even within the context of desk-based research such as the systematic review and rapid evidence review, as the researcher influences the data collected and its interpretation. Positionality should be more clearly recognized across all types of systematic reviews in order to increase transparency and replicability. In the case of Chapter 4, I come from an environmental/sustainability perspective, as opposed to a psychology or a

computer science perspective which is dominant across the included studies, which could affect the narrative synthesis.

The focus of this work is on individual behaviour change, and I work within the normative paradigm that individuals can collectively have a significant positive impact through direct change (i.e. consumption, purchasing) and indirect change (i.e. education, voting). There are many conceptual, methodological and practical challenges associated with focusing on individual behaviour, for instance around the ethical considerations of advocating for behavioural change (Gregg et al., 2022). However, I would like to emphasize the role that government and business have in restructuring and enabling pro-environmental behaviours and practices, and I work within the framework that system change can work in tandem with pushing individual level behaviour change forward. This extends to the theoretical discussion and fundamental underpinnings and assumptions of this work; broader systemic barriers to behaviour change cannot be overcome through individual-focused behavioural interventions such as VR. I recognise that and advocate that behavioural interventions are designed with broader systemic understanding of barriers to change in mind, through applying theory such as systems of provision (Bayliss et al., 2021), and considering fundamental issues such as equity, access and justice.

While most, if not all, PhD research journeys evolve in ways that cannot be anticipated, I believe it to be an important part of the PhD process to acknowledge the developments, decisions and factors which affected the end result of the research process. Throughout the PhD I have kept a research diary which has enabled me to look back and evaluate both the key decisions, the circumstances which impacted decisions, and the developments in priorities and thinking. By the nature of this research diary process, the most detail has focussed on the ‘sticking points’ of the PhD process, and it was used as a tool to work through them and document the development of thought throughout.

The research has changed, through organic evolution of skills and interests, and especially the multi-faceted impact of Covid-19 (outlined in more detail in discussion section 3.7). I think it is valuable to reflect critically on my own process and wider structural processes which created this final product.

A reflection on the methods chosen is useful in order to contextualise the choices made (personal and sometimes by circumstance). The original intention

of this PhD research was to examine the effectiveness of VR as a tool to encourage pro-environmental behaviour change. The research questions have changed over time in response to the findings from early stages of the work, especially from the systematic review, and in response to circumstance and logistical limitations. The systematic review was initially expected to synthesise a broader pool of research, therefore the dearth of research that existed during data collection (2018-2020) presented a new finding; namely that this research area was quite bounded in terms of research practice norms and disciplinary focus. It is worth noting that since this phase of work was conducted, the research area has expanded somewhat, however recent systematic reviews such as Fauville et al. (2020) and Cosio et al. (2023) corroborated many of the findings and limitations in Chapter 4.

A personal shift appears when examining the research diary, which is around the perception of which discipline I sit within or operate in. At the beginning of this research process, due to my sustainability background, I considered myself a sustainability researcher, and often felt uncomfortable in the first 18-24 months to refer to my work within a sphere broader than that. However, as an interdisciplinary researcher, the psychology research I was drawing on to develop the research plan and particularly the experimental design, as well as the healthcare research I drew on to develop the systematic and rapid evidence review methodologies made me question in which discipline/s I 'sat'. I mention this because of the assumptions and norms around research practice that are associated with different disciplines that feed into this work. For instance, the systematic review found assumptions around ethical practice in VR research which were uncommon in sustainability research. Therefore, this led to reflection on my own research design and research practice in Phase 3 of the work, as I aimed to integrate what I saw as best practice in sustainability research into VR work.

Working as an interdisciplinary researcher presents challenges. I now consider myself an environmental psychologist, or an environmental social scientist, however I still struggle with this label due to not having a background prior to this research in psychology. The disciplines this research brings together can sometimes feel siloed and therefore difficult to bridge (especially in regards to the computer-science based VR research). A significant barrier to truly

interdisciplinary work which integrates environmental social scientists with the environmental psychologists from a pure psychology background, is access to the underpinning data behind published research. A specific example of this is the use of metrics to measure determinants of behaviour. To those outside psychology, the lexicon can be impassable, and it could be argued that it is inherently detrimental to the discipline to make assumptions about a readership's knowledge of specific metrics. Moving towards a norm where full details of metrics and measures used within experimental research would significantly improve access to research, impact of findings and usefulness for readers and other researchers. As a minimum, a research protocol including the research design and metrics used (and how they are calculated) should be required to be published with all outputs, to avoid assumptions being made about how the research was conducted.

8.4 Limitations

There are several limitations of this work that are common across the three studies. These are largely methodological. The issue of sample size is found across all three phases. The systematic review only included a small number of studies, however more recent research identified a very similar numbers of studies (Cosio et al., 2023). The rapid evidence review of Phase 2 also synthesised a small number of studies, around a very specific research question. Both of these were conducted using a pre-defined research protocol, with one of the key components of systematic reviews being the boundaries around which the literature is searched. The systematic and methodical nature of the literature searching should provide confidence in the comprehensiveness of the included studies. However, there is the possibility due to the interdisciplinary nature of these research questions that lexicon differences could result in areas of work not being caught within the net of the search strings. In relation to the sample size of the experimental work, this was largely limited by the funds available for the reimbursement for participants (through the platform Prolific this is set at a minimum rate relative to the time taken).

One limitation of the work is due to the time period in which it has been conducted. Primarily catalysed by Covid-19, I chose to move to a part-time PhD

in 2021, for both professional and personal reasons, which has resulted in the thesis being conducted over 6 years. For instance, there may be a disconnect between the work conducted in 2018 (primarily the systematic review) and the context in which that work now sits, especially due to the expansion of work at the nexus of sustainability and VR over the last five years.

The final primary methodological limitation centres on the limitations associated with the metrics, measures and methods which are used. This work absorbs existing limitations associate with each component that is used. The systematic review found a dearth of research which utilised existing, externally validated metrics and sought to address this within the research, however that then presents issues with the limitations associated with metrics and methods being carried over into this work.

There are conceptual limitations, due to where the boundaries have been drawn around this research. This highly interdisciplinary area required boundaries to be drawn to facilitate decisions around research questions and research methods, as well as how findings are interpreted and applied. This research could have drawn on more computer science or technological elements of work, for instance in relation to immersion and presence, which are key variables in what impact VR has on an individual (Lee, 2004) (as Chapter 4 found). However, learning where and where not to explore and what is a useful ‘rabbit hole’ is one of the most important skills I have needed to develop throughout this research process. Geographic boundaries were drawn, with a focus on UK respondents in Chapter 6 and a broadly Western context for the reviews in Chapters 4 and 5. Understanding the application and interpretation of these non-Western contexts is imperative, as there is a need for more examination of behavioural theory in a global south context (Vishwanath et al., 2023).

There are some structural limitations which I feel are worth acknowledging. As a PGR, I have been afforded great freedom and trust to explore what I felt was worth exploring within this research project. However, there are structural limitations in place, in Leeds and within wider Higher Education, that have restrained the potential of this work. The limited power afforded to PGRs places us in a position where we are often expected to provide free labour in the form of being peer-reviewers, providing administrative support to panels or groups within the University, or providing expertise, under the guise of ‘experience’ or

‘training’. As we are considered to be either students or staff when it is most convenient, without the protection of either status. The financial provision has resulted in needing to take on a range of paid roles, and as mentioned above, moving to part-time. Only by providing job and financial security can PGRs conduct their best, most interesting and innovative research.

8.5 Recommendations for researchers

These reflections on the limitations of this research, and the findings from the systematic review and rapid evidence review present key insights for suggestions for future research, as well the research process.

Methodologically, as outlined above, common limitations were found across virtual reality and behavioural research. The dearth of longitudinal research limits the real-world application of findings, especially considering the decay rate measured over three weeks in Phase 3, across a range of behavioural factors. Focusing on developing research capacity for longitudinal work could increase the impact of this research. Similarly, the use of non-bespoke metrics of behaviour and behaviour change would enable buildable knowledge in this space.

Conceptually, a greater focus on high impact behaviours has been strongly advocated, especially in recent years (Lange et al., 2021; Cologna et al., 2022). This research supports that, with the potential for spillovers and co-benefits identified in relation to meat consumption behaviours in Phase 2, therefore future research into the potential for interventions (in particular VR) around specific high-impact behaviour. This was also identified as a critique of the VR-pro-environmental behavioural literature in Phase 1 of this research. Similarly, the impact of behavioural rebound effects is an under-researched area of work where VR could enable methodological and empirical development.

Throughout this work, psychological barriers have been the thread linking the three pieces together. The findings from each section advocate for greater inclusion of psychological barriers within pro-environmental behavioural theory and for empirical testing as components of behaviour. More work is needed to explore how psychological barriers manifest, how they interact with behavioural determinants, and the different contexts and settings in which they operate.

Reconceptualising behavioural theory and how we measure and consider behaviour to include psychological barriers aligns well with reconsidering behaviour as a holistic and non-linear process. This also aligns with logistical developments in facilitating longitudinal work which would enable behavioural interventions to be evaluated and analysed while considering behavioural determinants and barriers as non-linear and dynamic.

As outlined above (Section 8.1.1), there is opportunity for future research to explore ethical practice within the use of VR as a research tool, and explore how this is applied to content creation and intervention design.

8.6 References

Bayliss, K., Mattioli, G. and Steinberger, J. 2021. Inequality, poverty and the privatization of essential services: A 'systems of provision' study of water, energy and local buses in the UK. Competition & Change. 25(3–4), pp.478–500.

Berenguer, J. 2007. The Effect of Empathy in Proenvironmental Attitudes and Behaviors. Environment and Behavior. 39(2), pp.269–283.

Cologna, V., Berthold, A. and Siegrist, M. 2022. Knowledge, perceived potential and trust as determinants of low- and high-impact pro-environmental behaviours. Journal of Environmental Psychology. 79.

Cosio, L.D., Buruk, O. 'Oz', Fernández Galeote, D., Bosman, I.D.V. and Hamari, J. 2023. Virtual and Augmented Reality for Environmental Sustainability: A Systematic Review In: Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems [Online]. Hamburg Germany: ACM, pp.1–23. [Accessed 2 June 2023]. Available from: https://dl.acm.org/doi/10.1145/3544548.3581147.

Fauville, G., Bailenson, J.N. and Queiroz, A.C.M. 2020. Virtual reality as a promising tool to promote climate change awareness In: J. Kim and H. Song, eds. Technology and Health. Elsevier, pp.91–108.

Gillath, O., McCall, C., Shaver, P.R. and Blascovich, J. 2008. What can virtual reality teach us about prosocial tendencies in real and virtual environments? Media Psychology. 11(2), pp.259–282.

Gregg, E.A., Kidd, L.R., Bekessy, S.A., Martin, J.K., Robinson, J.A. and Garrard, G.E. 2022. Ethical considerations for conservation messaging research and practice. People and Nature. 00, pp.1–15.

Lange, F., Nielsen, K.S., Cologna, V., Brick, C. and Stern, P.C. 2021. Making theory useful for understanding high-impact behavior. A response to van Valkengoed et al. (2021). Journal of Environmental Psychology. 75.

Lee, K.M. 2004. Presence, Explicated. Communication Theory. 14(1), pp.27–50.

McCall, C. and Blascovich, J. 2009. How, When, and Why to Use Digital Experimental Virtual Environments to Study Social Behavior. Social and Personality Psychology Compass. 3(5), pp.744–758.

Pan, X. and Hamilton, A.F. de C. 2018. Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. British Journal of Psychology. 109(3), pp.395–417.

Parsons, T.D. 2015. Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. Frontiers in Human Neuroscience. 9.

Rees, R., Oliver, K., Woodman, J. and Thomas, J. 2009. Children's views about obesity, body size, shape and weight: a systematic review. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Sheppard, S.R. 2005. Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. Environmental Science & Policy. 8(6), pp.637–654.

Siegel, J.A., Calogero, R.M., Eaton, A.A. and Roberts, T.-A. 2021. Identifying Gaps and Building Bridges Between Feminist Psychology and Open Science. Psychology of Women Quarterly. 45(4), pp.407–411.

Vishwanath, V.N., Patil, B. and Chandrashekar, D. 2023. What's in the context? Motivations and implications of an integrated model of environmental behavior. IEEE Engineering Management Review., pp.1–15.

Chapter 9 Conclusions

This research aimed to examine the psychological barriers to pro-environmental behaviour change, with a specific examination on the use of virtual reality (VR) to overcome them. This was structured under three overarching research questions:

1. How has virtual reality been used to research pro-environmental behaviour?
2. What role do psychological barriers play in the pro-environmental behaviour change mechanism?
3. Can psychological barriers to pro-environmental behaviour change be overcome through VR?

The three research questions broadly map to the three empirical Chapters (4 to 6), with theoretical and conceptual overlap. This research considers individual pro-environmental behaviour as a holistic and dynamic process, with a specific focus on psychological barriers. This is applied as a critique of the prominence of existing paradigms within policy, practice and research which do not consider psychological barriers as component of behaviour in their own right.

This research found that existing work using virtual reality to explore pro-environmental behaviour tended towards conceptualising behaviour narrowly, or implicitly doing this by measuring a narrow band of behavioural determinants or outcomes. A systematic review (Phase 1, Chapter 4) found a focus on technological and experiential outcomes may be explained by the nascent state of the research in this space, but going forward, a deeper and broader examination of behavioural determinants, barriers and outcomes could help develop this research area. The key findings associated with the existing focus on small scale, low impact pro-environmental behaviours over short time frames helped determine the research design and research questions of Phase 2 and 3.

Therefore, a closer examination of a high-impact pro-environmental behaviour (meat consumption) was conducted through a rapid evidence review. This found that psychological barriers to reducing meat consumption mapped relatively cleanly on to the Kollmuss and Agyeman (2002) model of pro-

environmental behaviour which underpins this thesis. This supports the usefulness of this model as a framework to explain phenomena but also as a way to determine how to examine phenomena.

This integration of psychological distance and the Kollmuss and Agyeman (2002) model of pro-environmental behaviour was shown to categorise psychological barriers associated with meat consumption reduction comprehensively, therefore is utilised and further explored in Phase 3 (Chapter 6). A new conceptualisation of psychological barriers was identified here, with psychological barriers manifesting as ‘blocks’ to change, as well as ‘gaps’ between behavioural determinants which prevent positive change.

Through an experimental design, the insights and knowledge developed from Phases 1 and 2 were integrated to explore the impact of an environment-themed VR film on psychological barriers to pro-environmental behaviour. This chapter found that, as with the studies included in the systematic review (Chapter 4), that some a short-term increases in pro-environmental behavioural determinants, barriers and outcomes were identified. Psychological distance was found to be significantly reduced (i.e. improved) after experiencing the VR film, which indicates support for the assumptions present within the VR industry that VR reduces psychological distance. However, what remains unclear, and therefore an avenue for future research, is whether this translates to meaningful behaviour change.

This thesis presents novel contributions to the research area, the key contributions include:

Methodologically, critiques of systematic reviews and their application to environmental social sciences (presented in Chapter 3) argue that a more flexible understanding of this method could increase the rigour of literature reviews by enabling a broader array of research questions to apply this method.

Empirically, the evidence generated which supports the assumptions that virtual reality reduces the psychological distance experienced in relation to climate and environmental issues can be used to give confidence about its usefulness in this space.

Theoretically, integrating psychological distance with the Kollmuss and Agyeman (2002) model of pro-environmental behaviour increased the

comprehensiveness of this model, therefore this presents potential to shift dominant policy, practice and research paradigms to conceptualise behaviour in a more holistic, dynamic and useful way.

This research has integrated several areas of research (pro-environmental behavioural theory, psychological barriers, virtual reality and behavioural interventions). This approach has enabled the application of a critical lens through applying multi and interdisciplinary perspectives, which has generated insights for industry and research going forward. Virtual reality has potential to be a useful tool for communicating climate change and environmental issues, by reducing the psychological distance experienced.

This research has implications for how to talk about and communicate the risks, impacts and solutions associated with climate and environmental issues more broadly, by generating new insights into how psychological barriers to individual pro-environmental behaviour change can be overcome. The holistic conceptualisation of pro-environmental behaviour has empirically shown the importance of psychological distance within a broad understanding of the behavioural mechanism. Going forward in policy and practice, psychological distance and psychological barriers to pro-environmental behaviour change should be integrated into behaviour change interventions in order to create and evaluate more impactful change.

Appendices

Appendix A: Systematic review process

Research Questions:

This systematic review aims to answer the question: 'How has VR been used to affect and research environmental behaviour?'

Sub-questions:

- RQ1: How has virtual reality been found to affect pro-environmental behaviour?
- RQ2: How is virtual reality used as a research tool to study pro-environmental behaviour?
- RQ3: How is behavioural theory applied across pro-environmental behavioural change research?

Objective:

To assess all the literature and researched conducted (in English language), to ascertain an overview and synthesis of how VR is used as a tool to affect pro-environmental behaviour. This is to understand the current state of the research, identify methodology used across the research body, and provide theoretical underpinning for the study. The exploration and synthesis will also provide the basis for the methodology for the next stage of the research due to the methodology evaluation and quality assessment.

The exploration and synthesis will also provide the basis for the methodology for the next stage of the research due to the methodology evaluation and quality assessment.

Method:

Justification for approach:

The protocol has been developed in accordance with the advice provided in the Collaboration for Environmental Evidence Synthesis Assessment Tool guidelines (Woodcock et al., 2014). Frameworks were explored (e.g. PICOS), which lend themselves more to measuring the impact of an intervention on a population, and were found to be not

as applicable due to the population needing to be specified, the lack of comparison indicators and consistency across methodologies. This protocol has been developed to specifically address the research question 'How has VR been used to affect and research environmental behaviour?'.

Search strategy:

Scoping study and search string development:

A scoping study is required to ascertain the breadth of the existing literature in order to identify how to develop relevant search strings for the systematic review. This will be conducted by identifying key papers and developing a keyword concept map from these papers, ensuring a breadth of journal and methodological approach in order to ensure a breadth of language. The concept map will be developed from either keywords associated with the paper or keywords and themes extracted from the abstract or introduction, with synonyms identified and recorded.

The databases have been identified from the database list in Dundar and Fleeman (2017) in addition to subject specific database lists accessed from:
https://library.leeds.ac.uk/subjects/1179/psychology

https://library.leeds.ac.uk/subjects/1151/earth-and-environment

The specific search strings will be developed and applied to the relevant (and sometimes multiple) databases.

Depending on the specificity of the search results in relation to pro-environmental behaviour, the keyword search may have to be expanded to identify research which more broadly explores the use of virtual reality as a tool to change behaviour, and the application to pro-environmental behaviour may come in the synthesis.

Hand searching and coverage check:

In order to check comprehensiveness of the search, key authors have been identified due to the narrowness and relative novelty of the research area:

- Jim Blascovich;
- Sun Joo (Grace) Ahn;
- Jeremy Bailenson.

These authors have been identified as key in the research area due to their affiliation with the world-renowned Virtual Human Interaction Lab at Stanford University, which is the first lab which has focussed on pro-environmental behaviour using virtual reality. Their bibliographies will be checked against the database searches for relevant publications to ensure the search strings are returning key papers. If new publications are found, these will be added to the database in Zotero.

In addition to database searching, a search of Google Scholar will be conducted with a simplified search string in order to identify any grey literature or publications not already captured by previous database searches.

Once it is ensured that full coverage has been reached, and the database has been compiled, the searches will be re-run 4-8 weeks after the initial search is conducted in order to capture the most recent records.

The aim of a systematic review is to be comprehensive, not to achieve saturation (Petticrew, M. and Roberts, H., 2006).

Literature screening:

Exclusion/inclusion criteria:

Once all searches are complete and references compiled (in Zotero), duplicates will be removed and an initial sift of the title and abstract is undertaken with the application of inclusion/exclusion criteria. Due to resource restrictions, 10% of the initial results will be sifted separately by a second reviewer and any discrepancies around inclusion/exclusion shall be discussed. If there is more than 10% discrepancy, another 10% of results will be sifted by a second reviewer, and so on until discrepancies are removed.

Within the first sift, the title and abstract will be analysed for the presence of the three key concepts (environmental issues, virtual reality (in any format) and behaviour change (empathy, presence, awareness, action, intent to act, values (and related concepts/synonyms)). The initial sift is left intentionally broad in order to ensure that important studies are not missed, due to the diverse language applied in relation to this inter-disciplinary topic.

The second sift will be completed by the primary reviewer by analysing the full paper. Similar to the first sift, a supervisor will review 10% of the full papers to ensure agreement within the included/excluded studies. Discrepancies will be discussed and if there is more than 10% discrepancy, another 10% of results will be sifted by a second reviewer, and so on until discrepancies are removed.

The second sift inclusion criteria are outlined below, all must be reached to be included in the study.

	Inclusion	***Exclusion***
Language	English language only	Non-English language
Publication date	No date restrictions	No date restrictions
Databases	Academic literature: databases such as SCOPUS, Web of science, EBSCOhost (conference proceedings, academic publications), psycINFO. Grey literature: Google Scholar (NGO/Government reports)	
Methodology/type of study	Primary quantitative and qualitative studies.	Review studies
	VR used in methodology as the intervention or tool.	
	Extended reality methods applied should be explicitly immersive, i.e. headset or other immersive technology. Must explicitly be IVET (immersive virtual environment technology).	'Virtual environments' including computer-based screens, online games and other online platforms.

	Terminology generally which will indicate suitable technology/level of immersion: XR/Extended reality, Immersive technology, virtual reality.	
Conceptual	Virtual reality/XR theory should be applied to the study, or used as the methodological tool.	Hard medical literature (e.g. neuroscience or physiological effects of VR).
	Literature needs to address change in attitudes, values, intentions or behaviour (including the whole spectrum of behaviour including empathy, presence, awareness, education, intent to act, actions, long term change).	Engineering/computing literature with no human/social element.
		Behaviour change which does not relate to societal concepts/issues (i.e. physiological effects, treatment of disease or training/learning development)
	Explicit use of environmental issues as the context for behavioural study. This could be methodologically explicit, or discussed conceptually. This could also include behaviours which affect environmental issues	

	indirectly, but the link needs to be explicitly made.	
Participants/scope	Human behavioural study in any society/geography and at any scale (individual and social).	Non-human subjects

Table 1: Exclusion and inclusion criteria for systematic review.

The process and selection of results will be recorded in a PRISMA protocol.

Review Framework:

Once the full literature screening has been completed and the studies compiled, the literature must be reviewed systematically. This will be done through the application of a framework which aims to extract the methodological and theoretical underpinnings of the studies as well as the study design and results.

The data extracted will be mapped to the research questions therefore the questions inform the categories for extraction.

Data extraction categories:

Bibliographic information:

- Allocated reference code
- Date of extraction
- Reference (name, date)
- Full citation
- Journal
- Keywords used

Study Details

- RQ addressed
- Context - theoretical background and grounding

- Participants
- Scope and timeframe
- Methods
- Type of intervention (tech)
- Awareness/empathy/behaviours being studied
- Specific variables measured
- Study comparators
- Study outcomes
- Outcomes identified
- Factors/variables/processes identified to impact awareness/empathy/behaviour

How was success and impact measured?

- Wider implications (policy/practice impact)
- Future research
- Theoretical/conceptual development

Additional:

- Narrative summary of work

The review framework will be piloted using a selection of the key papers, covering a range of journals and disciplines to ensure appropriateness which is suitable for the interdisciplinary nature of the research area.

Critical Appraisal Framework (adapted from on (Rees et al., 2009))

1. Clear question outlined?
2. Sampling: Were steps taken to increase rigour in the sampling?

- Consider whether: *the sampling strategy was appropriate to the questions posed in the study (e.g. was the strategy well reasoned and justified?); *attempts were made to obtain a diverse sample of the population in question (think about who might have been excluded; who may have had a different perspective to offer); *characteristics of the sample critical to the understanding of the study context and findings were presented (i.e. do we know who the participants were in terms of, for example, basic socio-demographics, characteristics relevant to the context of the study, etc.).

3. Is it is clear what methods were used to collect data? (e.g. focus group, semi-structured interview etc.)?
4. Is the form of data clear (e.g. tape recordings, video material, notes etc.)?
5. The intervention and comparison conditions are thoroughly described
6. The measures are appropriate for the intervention's anticipated outcomes and population.
7. Has the researcher justified the methods chosen?
8. If methods were modified during the study, has the researcher explained how and why?
9. Is there an in-depth description of the analysis process?
10. Were the findings grounded in/supported by the data?
11. To what extent are contradictory data taken into account?
12. Has the researcher critically examined their role, potential bias and influence during research question development?
13. Has the researcher critically examined their role, potential bias and influence during data collection?
14. Are there sufficient details of how the research was explained to participants for the reader to assess whether ethical standards were maintained?
15. Narrative summary of quality and risk of bias

Synthesis

The synthesis is likely to include both qualitative, quantitative and mixed-methods studies, therefore the synthesis will need to reflect this.

Initially, the literature will be mapped due to the interdisciplinary nature of the research area. This will provide an overview of the type of research which has been conducted which answers the Research Question/s. This will also provide broader context for the subsequent synthesis as well as potentially providing a gap analysis.

A narrative synthesis will be conducted, due to the diversity of study approaches anticipated, as 'telling the story' can be supplemented by statistical analysis through this methodology (Popay et al., 2006). It is expected that there will be a section of literature focussing on quantitative results (primarily from the psychology and health disciplines) which may provide sufficiently similar study designs to enable a more quantitative synthesis of those relevant studies, which will sit within the broader narrative qualitative synthesis. This will not be classified as a meta-analysis as the variables and interventions will not be sufficiently similar, but this quantitative analysis may be able to be used to answer questions raised in the narrative synthesis.

Scoping search and search string development

Initial searches of the full research question of the project identified key papers (n=8). These were searched for keywords (either author-allocated keywords, or through keyword extraction from the abstracts and introductions) and compiled into a concept map.

- J. W. Smith (2015) 'Immersive Virtual Environment Technology to Supplement Environmental Perception, Preference and Behavior Research: A Review with Applications', Int. J. Environ. Res. Public Health, 12, 11486-11505
- Bailey, J.O., Bailenson, J.N., Flora, J., Armel, K.C., Voelker, D. and Reeves, B. 2015. The Impact of Vivid Messages on Reducing Energy Consumption Related to Hot Water Use. Environment and Behavior. 47(5), pp.570–592.
- Tarr, M.J. and Warren, W.H. 2002. Virtual reality in behavioral neuroscience and beyond. Nature Neuroscience. 5(Supp), pp.1089–1092

- Ahn, S.J. (Grace), Bailenson, J.N. and Park, D. 2014. Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. Computers in Human Behavior. 39, pp.235–245.
- Kort, Y.A.W. de, IJsselsteijn, W.A., Kooijman, J. and Schuurmans, Y. 2003. Virtual Laboratories: Comparability of Real and Virtual Environments for Environmental Psychology. Presence: Teleoperators and Virtual Environments. 12(4), pp.360–373.
- Shin, D. 2018. Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? Computers in Human Behavior. 78, pp.64–73.
- Ahn, S.J. (Grace), Fox, J., Dale, K.R. and Avant, J.A. 2015. Framing Virtual Experiences: Effects on Environmental Efficacy and Behavior Over Time. Communication Research. 42(6), pp.839–863.
- Blascovich, J., Loomis, J., Beall, A.C., Swinth, K.R., Hoyt, C.L. and Bailenson, J.N. 2002. Target Article: Immersive Virtual Environment Technology as a Methodological Tool for Social Psychology. Psychological Inquiry. 13(2), pp.103–124.

The keyword searches were compiled into a search strategy to identify the impact of VR on different elements of behaviour change which had been extracted from the key paper keyword analysis. Other keywords were identified (i.e. synonyms/similar concepts such as augmented reality) as necessary to ensure a comprehensive search. These were trialed and adapted based on relevance of results; for instance, ‘virtual environment’ was removed due to high frequency of literature on physiological effects of computer usage. The results from the full searches were sense checked by ensuring the 8 key articles appear in the results, in addition to checking against bibliographies of key authors (Ahn, Bailenson and Blascovich).

Search strings and databases used:

There was found to be a lack of a consistent language within the VR-behaviour change sphere, potentially due to the inherent interdisciplinarity of the research, therefore a wide range of search strings and strategies were formulated. This is to balance specificity with sensitivity (Snape et al., 2017), and due to the specific nature of the research question, it

was deemed more prudent to run several narrow search strategies in order to create a wider, more comprehensive initial sift as opposed to a purely VR-environmental behaviour change search. This was also to allow for the lack of a common lexicon around this discipline.

Hand-searching

The final check to ensure sufficient coverage of the literature used key academics from the primary VR-behaviour lab (Stanford Virtual Human Interaction lab (VHIL)) – through identifying relevant publications and citation searching their outputs. These were identified from the scoping searches and the widespread prominence and reputation of the VHIL, of which the three key authors are past or current members.

The authors (Ahn, Bailenson and Blascovich) publication catalogues were identified (using ResearchGate and Google Scholar), and publications not already identified as key papers were downloaded. Citation searches of these key papers were then undertaken to ensure that relevant literature was captured in database searches. These were downloaded into Zotero.

Search strings

Database	Search string
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “Immersive virtual environment*” OR “augmented reality” OR “XR”) AND TITLE-ABS-KEY (“experiment” OR “tool” OR “intervention”) AND TITLE-ABS-KEY (“belief*” OR “value*” OR “environment* behavio?r* intent*” OR “attitud*”) AND TITLE-ABS-KEY (behavio?r*))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “Immersive virtual environment*” OR “augmented reality” OR “XR”) AND TITLE-ABS-KEY (“experiment” OR “tool” OR “intervention”) AND TITLE-ABS-KEY ((“belief*” OR “value*” OR “behavio?r*” OR “attitud*”) W/5 environment*) AND TITLE-ABS-KEY (behavio?r*))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “Immersive virtual environment*” OR “augmented reality” OR “XR”) AND TITLE-ABS-KEY ((“belief*” OR “value*” OR “behavio?r*” OR “attitud*”) W/5 environment*) AND TITLE-ABS-KEY (“experiment” OR “tool” OR “intervention”))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “VR” OR immersive AND environment OR “augmented reality”) AND TITLE-ABS-KEY (“experiment” OR “tool” OR “intervention”) AND TITLE-ABS-KEY (“belief” OR “value” OR “intention” OR “attitude”) AND TITLE-ABS-KEY (“behavio?r*”))
WOS	TS= (“virtual reality” OR “VR” OR immersive AND environment OR “augmented reality”) AND TS= (“experiment” OR “tool” OR “intervention”) AND TS= (“belief” OR “value” OR “intention” OR “attitude”) AND TS= (“behavio?r*”)

SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TITLE-ABS-KEY ((“behaviour*” OR “behavior*”) W/5 change) AND TITLE-ABS-KEY (“experiment” OR “tool” OR “method” OR “intervention”))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TITLE-ABS-KEY ((“behaviour*” OR “behavior*”) W/5 change) AND TITLE-ABS-KEY (“belief*” OR “value*” OR “attitud*”))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TITLE-ABS-KEY ((“behaviour*” OR “behavior*”) W/5 change) AND TITLE-ABS-KEY (“empath*”))
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TITLE-ABS-KEY (“Environment* behavio*”))
psycinfo	((“virtual reality” or “immersive environment” or “augmented reality”) and Environment behavi?r).af
WOS	TS= (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TS= ((“behaviour*” OR “behavior*”) change) AND TS= (“experiment” OR “tool” OR “method” OR “intervention”)
WOS	TS= (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TS= ((“behaviour*” OR “behavior*”) near/3 change) AND TS= (“empath*”)
WOS	TS= (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TS= (“behavio*”) AND TS= (“Embodied experience” OR “presence”)
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “immersive environment” OR “augmented reality”) AND TITLE-ABS-KEY (“Embodied experience” OR “presence”) AND TITLE-ABS-KEY (“behavio*”))

WOS	TS= (“virtual reality” OR “VR” OR “immersive virtual” OR “virtual environment*” OR “augmented reality”) AND TS= (“experiment* research” OR “research tool” OR “social psycholog*” OR “intervention” OR “method*”) AND TS= (“value*” OR “belief*” OR “intention*” OR “empath*”) AND TS= (behavio*)
SCOPUS	(TITLE-ABS-KEY (“virtual reality” OR “augmented reality” OR “immersive environment”) AND TITLE-ABS-KEY (“sustainable development goals” OR “climate change”))
ProQuest	ab(“virtual reality” OR “augmented reality” OR “immersive environment”) AND ab(“sustainable development goals” OR “climate change”)
Scholar	“virtual reality” (“behavior change” OR “behaviour change”) “climate change”

Table 2: Search strings and respective database used

References

Dundar, Y. and Fleeman, N. 2017. Developing my search strategy In: Doing a systematic review: A student's guide. Sage.

Petticrew, M. and Roberts, H. 2006. Systematic reviews in the social sciences. Blackwell Publishing.

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M. and Britten, N. 2006. Guidance on the Conduct of Narrative Synthesis in Systematic Reviews. , p.92.

Rees, R., Oliver, K., Woodman, J. and Thomas, J. 2009. Children's views about obesity, body size, shape and weight: a systematic review. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Snape, D., Meads, C., Bagnall, A.-M., Tregaskis, O., Mansfield, L. and MacLennan, S. 2017. A guide to our evidence review methods. What Works Wellbeing.

Woodcock, P., Pullin, A.S. and Kaiser, M.J. 2014. Evaluating and improving the reliability of evidence syntheses in conservation and environmental science: A methodology. Biological Conservation. 176, pp.54–62.

Appendix B: Rapid evidence review process

Inclusion/exclusion criteria

Inclusion/exclusion criteria:		
	Inclusion	Exclusion
Population	European, ideally UK based research. N > 10 (if experimental)	Children Non-humans n < 10
Intervention	Psychological barriers to behaviour change	Medical interventions (i.e. health-related research). Environmental structuring
Comparison	Different psychological barriers and subsequent impacts	
Outcomes	Behavioural actions: Measured actual meat consumption or intended meat consumption And: Behavioural determinants: psychological barriers, values, attitudes, habits	
Study design	Empirical study Experimental Quasi-experimental Qualitative	Theoretical Modelling Review
Study design context	Real-world	Lab-based (in order to ensure external validity of measures)

Conceptual	Psychological barriers Reduced meat consumption Increased meat alternatives Move to vegetarianism/veganism/ pescatarianism/flexitarianism/ climate-friendly diet/ sustainable food consumption etc. Climate-friendly/ eco-friendly/ sustainable consumption	Health-related behaviour change
Time	Since 2010	Pre 2010
Type of publication	Academic publications Grey Literature (Gov. reports, NGO reports, third party consultant reports etc.)	Anything else, i.e. media, blogs, theses.
		If full text not available through University of Leeds. Non-English language

Table 3: Rapid evidence review inclusion/exclusion criteria.

Search strings and returned results

Date searched	Database and Indexes	Search string	Results returned	Downloaded	Date Downloaded
10/03/2020	WOS (Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=All years)	TOPIC: (behav* OR intake OR consum* OR eat* OR drink* OR buy* OR purchas* OR spend* OR choice OR choos*) AND TOPIC: (meat replace* OR “plant-based” OR “vegan*” or “vegetarian*” or reduce meat consum*) NOT TOPIC: (child* OR adolescent* OR infant* OR baby OR babies OR toddler* OR teenager* OR pregnan* OR weaning) NOT TOPIC: (“major clinical study” OR “controlled clinical trial”) AND TOPIC: (“value” OR “belief” OR “intent*” OR barrier OR psycholog*) AND TOPIC: (climate OR carbon)	131	131	10/03/2020
10/03/2020	Scopus	(TITLE-ABS-KEY (behav* OR intake OR consum* OR eat* OR drink* OR buy* OR purchas* OR spend* OR choice OR choos*) AND TITLE-ABS-KEY (meat AND replace* OR “plant-based” OR “vegan*” OR “vegetarian*” OR reduce AND meat AND consum*) AND TITLE-ABS-KEY (“value” OR	87	87	10/03/2020

		“belief” OR “intent*” OR barrier OR psycholog*) AND TITLE-ABS-KEY (climate OR carbon) AND NOT TITLE-ABS-KEY (child* OR adolescent* OR infant* OR baby OR babies OR toddler* OR teenager* OR pregnan* OR weaning) AND NOT TITLE-ABS-KEY (“major clinical study” OR “controlled clinical trial”))			
10/03/2020	Google Scholar	psychological “barrier” meat consumption vegetarianism veganism climate carbon	1640 (200 sifted)	29	10/03/2020

Table 4: Search string and data recording table.

PRISMA flow diagram

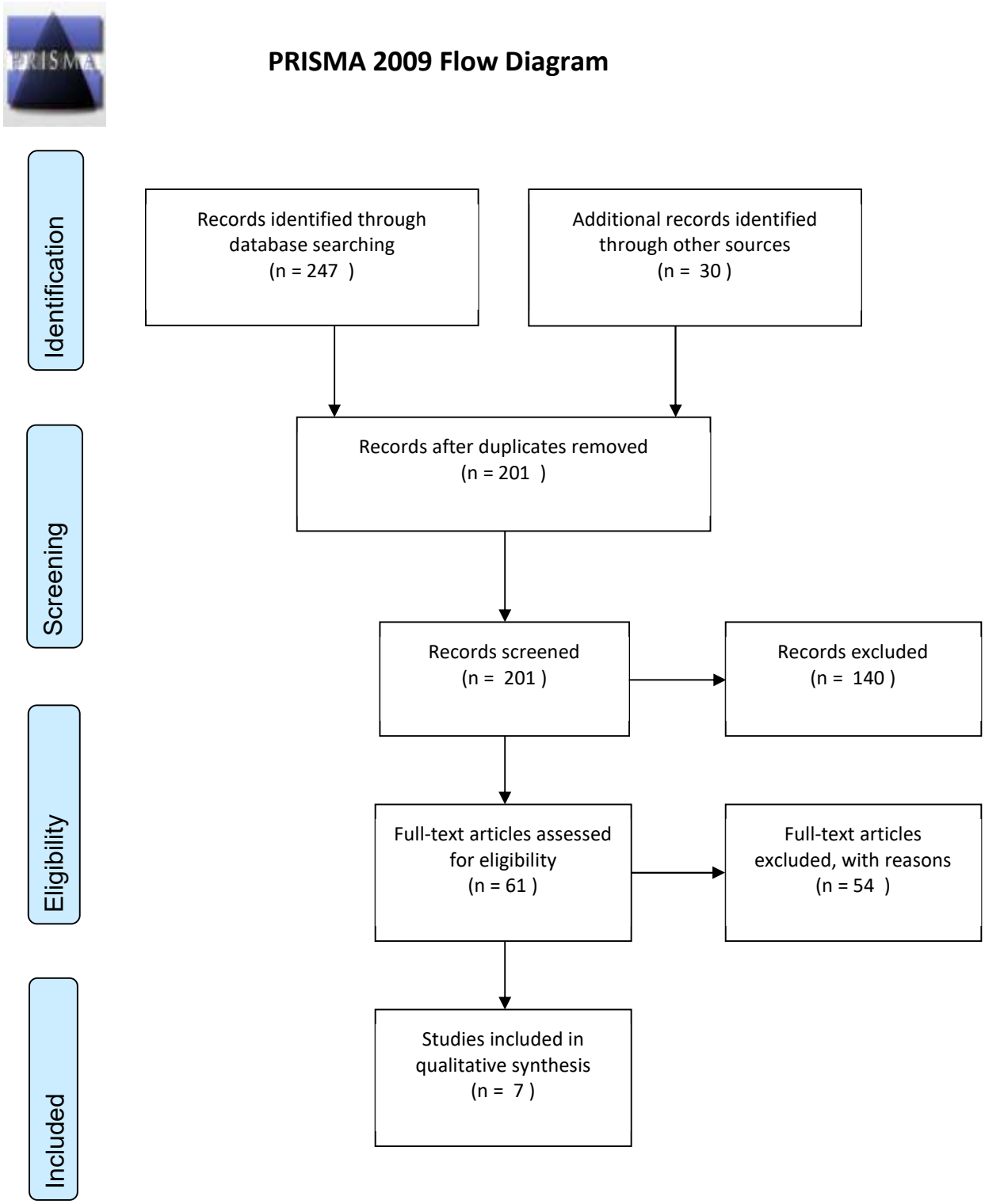


Figure 1: PRISMA flow diagram for rapid evidence review of psychological barriers to reducing meat consumption.

Data extraction framework questions

Study Design

- Code
- Date of review
- Reference
- Full citation
- Journal
- keywords used
- Research Question addressed / hypotheses
- Participants (sample size etc.)
- Spatial context, timeframe
- Study design
- Specific barriers measured
- Metrics used
- Other psychological determinants measured
- External factors measured (co-variants)
- Theoretical framework applied

Findings

- Main findings
- Dependent variable (‘behavioural outcome’ measured with metric)
- Impact of barriers measured
- Explanation
- Effect of co-variates/other variables
- Type of analysis conducted

- Factoral analysis? (distinction/exploration between barriers/variables)
- Impact on intended/ actual meat consumption
- Policy recommendations (how can barriers be overcome?)
- Future research
- Acknowledged limitations

- Reviewer's narrative summary
- Notes

Critical Appraisal (adapted from Rees et al. (2009))

- Code
- Date of review
- Reference
- Full citation
- Were steps taken to increase rigour in the sampling? Consider whether: *the sampling strategy was appropriate to the questions posed in the study (e.g. was the strategy well reasoned and justified?); *attempts were made to obtain a diverse sample of the population in question (think about who might have been excluded; who may have had a different perspective to offer); *characteristics of the sample critical to the understanding of the study context and findings were presented (i.e. do we know who the participants were in terms of, for example, basic socio-demographics, characteristics relevant to the context of the study, etc.).

Score /3

- Were steps taken to increase rigour in the data collected? Consider whether: *data collection tools were piloted/(and if quantitative) validated; *(if qualitative) data collection was comprehensive, flexible and/or sensitive enough to provide a complete and/or vivid and rich description of people's perspectives and experiences (e.g. did the researchers spend sufficient time at the site/with participants? Did they keep 'following up'? Was more than one method of data collection used?); * steps were taken to ensure that all participants were able and willing to contribute (e.g. processes for consent, language barriers, power relations between adults and children/young people).

Score /3

- Were steps taken to increase rigour in the analysis of the data? Consider whether: * data analysis methods were systematic (e.g. was a method described/can a method be discerned?); *diversity in perspective was explored; * (if qualitative) the analysis was balanced in the extent to which it was guided by preconceptions or by the data); *the analysis sought to rule out

alternative explanations for findings (in qualitative research this could be done by, for example, searching for negative cases/exceptions, feeding back preliminary results to participants, asking a colleague to review the data, or reflexivity; in quantitative research this may be done by, for example, significance testing).

Score /3

- Were the findings of the study grounded in/ supported by the data? Consider whether: *enough data are presented to show how the authors arrived at their findings; *the data presented fit the interpretation/support claims about patterns in data; *the data presented illuminate/illustrate the findings; *(for qualitative studies) quotes are numbered or otherwise identified and the reader can see that they don't just come from one or two people.

Score /3

- Please rate the findings of the study in terms of their breadth and depth.

  Consider whether: (NB: it may be helpful to consider 'breadth' as the extent of description and 'depth' as the extent to which data has been transformed/analysed); *a range of issues are covered; * the perspectives of participants are fully explored in terms of breadth (contrast of two or more perspectives) and depth (insight into a single perspective); *richness and complexity has been portrayed (e.g. variation explained, meanings illuminated); *there has been theoretical/conceptual development.

Score /3

- What weight would you assign to this study in terms of the usefulness of its findings for this review? Consider: *the match between the study aims and findings and the aims and purpose of the synthesis; *its conceptual depth/explanatory power.

Score /3

- Total score (/18)
- Low/medium/high classification
- Narrative assessment

Appendix C: Experimental design

[[text in italics is for the benefit of Ethical Review and do not appear in the survey]]

Website text

Are you interested in virtual reality and have your own VR headset? Want to contribute to research in VR?

We are exploring the role VR can play in changing behaviours, and need participants to take part in a short experiment (virtually, in the comfort of your own home at a time of your choosing) to play a crucial role in building knowledge around the impact of VR.

What will the experiment involve?

It will involve two short surveys, and it might involve watching a short film in VR – the total time for the experiment will be no more than 30 minutes. There will be another short follow up survey approximately two weeks after the initial survey. There may be opportunity to be involved in the next stage of the research, which involves short interviews with participants.

If you are interested in participating, you can find out more information and sign up here: [LINK TO ONLINE SURVEY].

Participant information sheet

Thank you for your interest in participating!

Title of Research Project: Virtual Reality and pro-environmental behaviour change.

This page will hopefully provide you with enough information about the study to allow you to make an informed decision about your participation. However, if you have any questions or would like to discuss anything, please do not hesitate to contact Catherine Graves (ee14cg@leeds.ac.uk).

Please read this information carefully in order to understand the study rationale and what taking part involves. You can then make an informed decision as to whether you wish to participate.

This research project aims to explore if and how Virtual Reality impact an individual's behaviour. Understanding behaviour change mechanisms in relation to VR is an under-researched area and participation in this study is directly contributing to building this knowledge.

Participation in this study is entirely voluntary. Through Prolific, you will be compensated for your time at a rate of £8/hour (although the study will take between 15-45 minutes).

After reading this information, you will be invited to complete and sign a consent form to indicate that you understand what is involved in the study and that you wish to take part. You will then be taken through to the Health Screening Questionnaire and pre-test Questionnaire.

The criteria listed below outline essential prerequisites of the study:

❑ Over 18 years of age

❑ Have access to suitable VR equipment (head-mounted display) and are able to fit and calibrate equipment fully

❑ Understand the health risks associated with using Virtual Reality (i.e. dizziness, cyber-sickness etc.)

❑ No previous history of severe brain injury, brain surgery

❑ No previous history of taking any neurological/psychotropic medication;

❑ No previous history of cardiovascular related (heart) problems

❑ Must not be taking any medication for psychiatric/neurological illness

❑ Must not have any history of visual disorder (partial or complete blindness, visual disturbances, etc.) or motor disorder (tremors, spasms, etc.)

What is involved?

The experiment will take no more than 45 minutes. As a part of the study:

- You *may* be asked to wear a Head-Mounted Virtual Reality display.

- You *may* be asked to complete a short Post-Test Questionnaire.
- You will be given the opportunity to continue your involvement in the research project through to the next phase if you so wish. Details of this will be given at the end of the study, with no obligation to continue.

Any personal information you provide will remain strictly confidential and will not be passed to other parties. If information collected in this study is published in scientific journals, participants will be referred to by an anonymous code only. The terms of the Data Protection Act 2018 will be adhered to and information will be securely stored. If you would like to withdraw from the experiment, you can do this without having to give a reason. You will be able to withdraw your data before the analysis process of the data begins (one month after your experiment date). Lastly, participants do not have any claim over intellectual property rights that may emerge from the research and should not disclose anything about the experiment to others.

Please continue to the Health Screening Questionnaire and the Consent Form to participate.

Ethics number: XXXXXXX

Approval date: XXXXXXX

***Lead Researcher*:** Catherine Graves (ee14cg@leeds.ac.uk)

***Supervisors*:** Dr. Katy Roelich (k.e.roelich@leeds.ac.uk), Dr. Milena Buchs (m.m.buchs@leeds.ac.uk)

***Address*:** Priestley International Centre for Climate, School of Earth and Environment, University of Leeds, LS2 9JT.

Health and safety screening questionnaire

Using Virtual Reality equipment carries some risks associated with dizziness, cyber sickness, eye strain and other illnesses. Please read the equipment manufacturers guidance for full details of associated risks. If at any point you feel unwell, stop the experiment and remove the headset. You can withdraw from the experiment at any point without needing to give a reason.

Due to these risks, this health screening questionnaire is required, and if a risk is identified, unfortunately you will not be able to take part.

Screening Questionnaire

***Researcher*:** Catherine Graves (ee14cg@leeds.ac.uk)

***Supervisors*:** Dr. Katy Roelich (k.e.roelich@leeds.ac.uk), Dr. Milena Buchs (m.m.buchs@leeds.ac.uk)

Please complete the following questions for screening purposes.

	I confirm:	YES	NO
1	I am over 18 years of age		
2	I have normal to corrected vision and hearing		
3	To the best of your knowledge, have you ever suffered from any of the following: brain/neurological condition, complete blindness, visual disturbances, motor disorders, tremors or spasms?		
4	Are you currently taking any neurological/psychotropic medication such as: - Anticonvulsants/antiepileptics		

	- Antidepressants - Tranquillizers - Neuroleptics - Antipsychotics (Please answer yes if you are taking any of these or any neurological/psychoactive medication that is not included in the list above)		
5	To the best of your knowledge, do you have any pre-existing binocular vision abnormalities or psychiatric disorders, or suffer from a heart condition or other serious medical condition?		
6	I have access to suitable VR equipment (head-mounted display) and are able to fit and calibrate equipment fully		
7	I understand the health risks associated with using Virtual Reality (i.e. dizziness, cyber-sickness etc.)		

Consent form (phase 1; survey and experiment)

Thank you for completing the health screening questionnaire.

Tick the box if you agree with the statement to the left		
1	I confirm that I have read and understood the information page explaining the research project and I have had the opportunity to ask questions about the project.	
2	I understand that my participation is voluntary and that I am free to withdraw at any time (until 1 month after the date of the experiment) without giving any reason. In addition, should I not wish to answer any particular question or questions, I am free to decline.	
3	I understand the risks associated with using virtual reality equipment and can properly calibrate and fit the headset.	
4	I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. If information collected in this study is published in scientific journals, where necessary, participants will be referred to by an anonymous code only. The terms of the Data Protection Act 2018 will be adhered to and information will be securely stored.	
5	I agree for the data collected to be used in future research as part of this project, or related research projects in an anonymised form.	
6	I agree to take part in the above research project and will inform the lead researcher should my contact details change.	

Pre-test survey (intervention)

Thank you for completing the health screening.

This first survey aims to understand more about how you think and feel about environmental issues, please answer as honestly as you can, all answers will be anonymised after the study is complete.

Intervention only question:

What VR headset/equipment will you be using for this experiment? (free text) e.g. Oculus Quest	

Demographics

Please complete the following demographic questions:

Gender	Female
	Male
	Non-binary
	Prefer Not To Say
Age	18-24
	25-34
	35-44
	45-54
	55-64
	65-74

	75 Or Over
Annual income	Up To £9,999
	£10,000 To £19,999
	£20,000 To £29,999
	£30,000 To £39,000
	£40,000 And Above
Highest general qualification	No Formal Qualifications
	GCSE/O-Level
	A-Level/Higher/BTEC
	Vocational/NVQ
	Degree or Equivalent
	Postgraduate Qualification
	Other
	Unknown
Location (free text) (City/County, Country) *optional	

Adapted from (Whitmarsh, 2008)

How often do you use VR?	Everyday

	More than once a week
	More than once a month
	Rarely

Revised New Ecological Paradigm scale (Dunlap et al., 2000)

The Revised NEP: Items and Factors as Listed in Dunlap, van Liere, Mertig, and Jones (2000)

Next, listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you STRONGLY AGREE, MILDLY AGREE, are UNSURE, MILDLY DISAGREE or STRONGLY DISAGREE with it.

1. We are approaching the limit of the number of people the earth can support

2. Humans have the right to modify the natural environment to suit their needs

3. When humans interfere with nature it often produces disastrous consequences

4. Human ingenuity will insure that we do NOT make the earth unlivable

5. Humans are severely abusing the environment

6. The earth has plenty of natural resources if we just learn how to develop them

7. Plants and animals have as much right as humans to exist

8. The balance of nature is strong enough to cope with the impacts of modern industrial nations

9. Despite our special abilities humans are still subject to the laws of nature

10. The so-called “ecological crisis” facing humankind has been greatly exaggerated

11. The earth is like a spaceship with very limited room and resources

12. Humans were meant to rule over the rest of nature

13. The balance of nature is very delicate and easily upset

14. Humans will eventually learn enough about how nature works to be able to control it

15. If things continue on their present course, we will soon experience a major ecological catastrophe

("Question wording: "Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you STRONGLY AGREE, MILDLY AGREE, are UNSURE, MILDLY DISAGREE or STRONGLY DISAGREE with it." Agreement with the eight odd-numbered items and disagreement with the seven even-numbered items indicate pro-NEP responses" (p433, Dunlap et al., 2000))

Connectedness with nature scale (Ahn et al., 2016)

Connectedness with Nature (1 = Not at all; 5 = Very strongly) (reverse-coded question)*

The following statements explore human connection with nature. For each of the following statements, rate them on a scale from 1 (Not at all) to 5 (Very strongly):

I often feel a sense of oneness with the natural world around me.

I think of the natural world as a community to which I belong.

I recognize and appreciate the intelligence of other living organisms.

I often feel disconnected from nature.*

When I think of my life, I imagine myself to be part of a larger cyclical process of living.

I often feel a kinship with animals and plants.

I feel as though I belong to the Earth as equally as it belongs to me.

I have a deep understanding of how my actions affect the natural world.

I often feel part of the web of life.

I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force.'

Like a tree can be a part of a forest, I feel embedded within the broader natural world.

When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature.*

I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.

My personal welfare is independent of the welfare of the natural world.*

Environmental knowledge (van der Linden, 2015)

	Impact-Knowledge Items (Index)
(1 = Likely to Decrease 2 = No Change, 3 = Likely to Increase, 4 = Don't know)	Global sea level, acid rain, melting of glaciers and polar ice caps, areas in the world experiencing drought, global spread of infectious disease, air pollution, global average temperature, extreme weather events (e.g., flooding, hurricanes, etc.), global biodiversity (i.e., variety of plants and animals), volcanic eruptions, the hole in the ozone layer, frequency of hot days and nights, global fresh water supply.
Measurement Scale	**Knowledge about Climate Change**
(1 = Major, 2 = Minor, 3 = No Contribution to Climate Change, 4 = Don't know)	Driving a car, the sun, burning fossil fuels (coal, oil, gas) for heat and electricity, the hole in the ozone layer, flying / commercial air travel, toxic waste, steadily rising CO2 emissions (carbon dioxide), aerosol spray cans (containing CFC's), nuclear power plants, agricultural activities such as cattle breeding (cows raised for meat consumption), acid rain, deforestation (e.g., destruction of rainforests), smoking cigarettes.
	Cause-Knowledge Items (Index)

For the following questions, select to what extent each item (e.g., burning fossil fuels) contributes to climate change.

For the following questions, estimate whether each item (e.g., global sea level) is likely to increase, decrease or not change at all as a result of climate change.

For the following questions, rate how much each item (e.g., conserving energy) is likely to reduce climate change if done worldwide.

	Response-Knowledge Items (Index)
(1 = Reduce climate change a lot, 2 = Reduce climate change a little, 3 = Not going to reduce climate change at all, 4 = Don't know)	Switching from fossil fuels to renewable energy (wind, solar, geothermal), generating less toxic waste (nuclear, chemical), recycling paper, glass and plastic, insulating buildings, reducing (commercial) airline flights, conserving energy, purchasing only organic products, fixing the hole in the ozone layer, switching from petrol to electric cars, becoming a member of an environmental group, eating less meat, using more public transportation, planting trees.

Barriers:

Psychological Distance (Spence et al., 2012)

For the following questions and statements, select the response which best fits your opinion on climate change.

Construct	Question	Response Options
Geographic distance	"My local area is likely to be affected by climate change."	5-point scale (Strongly agree–Strongly disagree)
	"Climate change will mostly affect areas that are far away from here."	5-point scale (Strongly agree–Strongly disagree)
Social distance	"Climate change will mostly affect developing countries."	5-point scale (Strongly agree–Strongly disagree)
	"Climate change is likely to have a big impact on people like me."	5-point scale (Strongly agree–Strongly disagree)
Temporal distance	"When, if at all, do you think Britain will start feeling the effects of climate change?"	7-point scale (We are already feeling the effects–Never)
Uncertainty/scepticism	"Thinking about the causes of climate change, which, if any, of the following best describes your opinion?"	6-point scale (Entirely natural processes–Entirely human activity, I think there is no such thing)
	"I am uncertain that climate change is really happening."	5-point scale (Strongly agree–Strongly disagree)
	"The seriousness of climate change is exaggerated."	5-point scale (Strongly agree–Strongly disagree)

	“Most scientists agree that humans are causing climate change.”	5-point scale (Strongly agree–Strongly disagree)
	“It is uncertain what the effects of climate change will be.”	5-point scale (Strongly agree–Strongly disagree)

Meat consumption:

Question	Response Options
How often do you eat meat?	More than once a day
	Once a day
	More than 3 times a week
	Less than 3 times a week
	Rarely
	Never
Attitude toward reducing meat consumption *(Povey et al., 2001)* *(on 5 point Likert scale)*	Bad – Good (Attitude1)
	Harmful – Beneficial
	Unpleasant – Pleasant
	Unenjoyable – Enjoyable

Adapted from: Cheah et al. (2020); (Povey et al., 2001)

Recurring Pro-environmental Behaviour Scale (REBS) (adapted from Brick, Sherman and Kim, 2017)

“Now, please respond to these questions about your behaviour.

Don't feel any pressure, just indicate what you choose to do. Items are rated 1 (Never), 2 (Rarely), 3 (Sometimes), 4 (Often) or 5 (Always).

Adapted (UK language – i.e. shop instead of grocery store):

1. When you visit the food shop, how often do you use reusable bags?

2. How often do you walk, bicycle, carpool, or take public transport instead of driving a car by yourself?

3. How often do you drive slower than 60mph on the motorway?

4. How often do you go on personal (non-business) air travel?

5. How often do you compost your household food waste?

6. How often do you eat meat?

7. How often do you eat dairy products such as milk, cheese, eggs, or yoghurt?

8. How often do you eat organic food?

9. How often do you eat local food (produced within 100 miles)?

10. How often do you eat from a home vegetable garden (during the growing season)?

11. How often do you turn your personal electronics off or in low-power mode when not in use?

12. When you buy light bulbs, how often do you buy high efficiency compact fluorescent (CFL) or LED bulbs?

13. How often do you act to conserve water, when showering, cleaning clothes, dishes, watering plants, or other uses?

14. How often do you use aerosol products?

15. When you are in public, how often do you sort waste into the recycling?

16. When you are in private, how often do you sort waste into the recycling?

17. How often do you discuss environmental topics, either in person or with online posts (Facebook, Twitter, etc.)?

18. When you buy clothing, how often is it from environmentally friendly brands?

19. How often do you carry a reusable water bottle?

20. How often do you engage in political action or activism related to protecting the environment?

21. How often do you educate yourself about the environment?

Post-test survey

Thank you for watching the VR content; please complete this survey.

As pre-test questionnaire:

- *Revised New Ecological Paradigm scale (Dunlap et al., 2000)*
- *Connectedness with nature scale (Ahn et al., 2016)*
- *Environmental knowledge (van der Linden, 2015)*
- *Psychological Distance (Spence et al., 2012)*

With additional questions:

Presence:

Presence ((Soliman et al., 2017) Adapted From Witmer & Singer, 1998) (Likert 1-7 scale)

For the following questions, select how you felt about the VR experience:

How involved were you in the virtual environment experience?

How completely were all of your senses engaged?

How much did the visual aspects of the environment involve you?

How much did the auditory aspects of the environment involve you?

How inconsistent or disconnected was the information coming from your various senses? [reverse coded]

How much did your experiences in the virtual environment seem consistent with your real-world experiences?

To what degree did you feel confused or disoriented during the experimental session? [reverse coded]

How completely were you able to actively survey or search the environment using vision?

How well could you identify sounds?

How well could you localize sounds?

How aware were you of events occurring in the real world around you? [reverse coded]

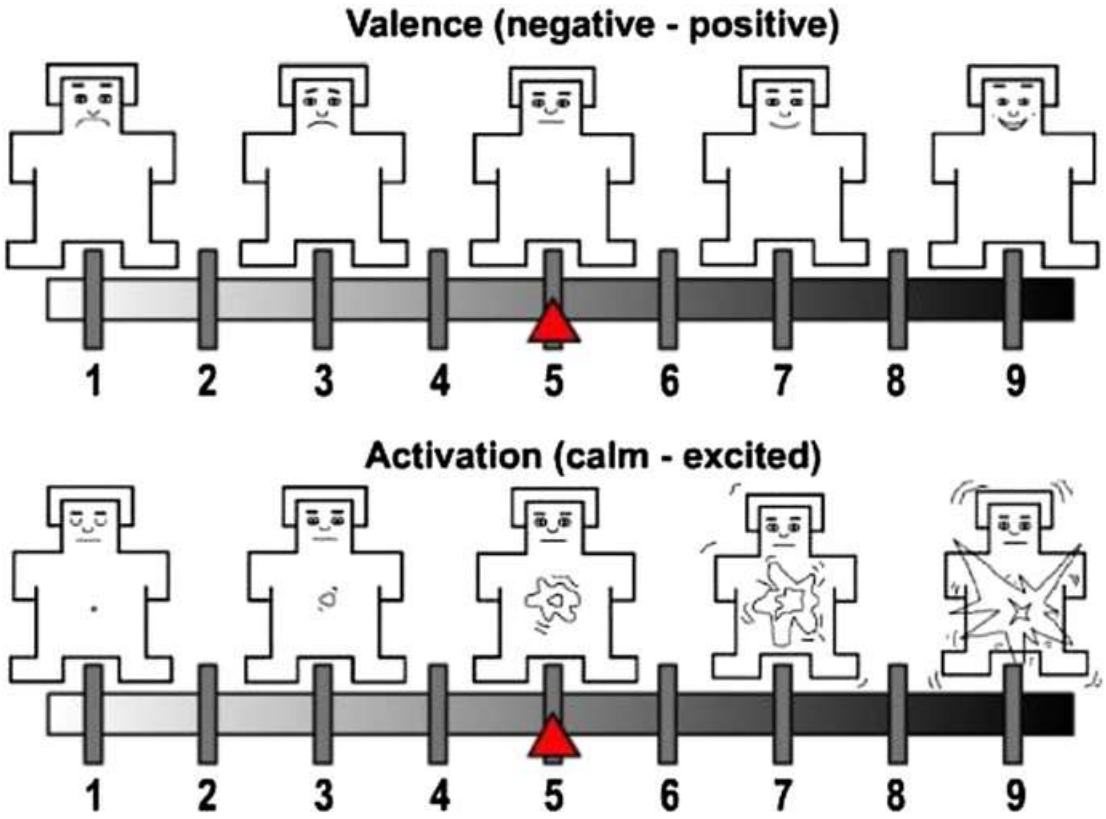
How aware were you of your display devices? [reverse coded]

How well could you concentrate on the video itself rather than on the mechanisms used to display that video?

Emotional response

Self-Assessment Manikin (SAM) (Giacomin and Bertola, 2012) First created by (Bradley and Lang, 1994)

And finally, select the number/picture which best represents how you feel about the experience.



Contact information

This information is collected in order to contact you with the follow up survey. The information will not be shared with anyone but the primary researcher and is held on a secure server.

Name:

Email address:

Participant debrief (intervention)

Thank you very much for completing this survey, you will receive an email in two weeks with a link to the final survey. Please do look out for this and complete it, as this will really help build our understanding of the impact of VR.

If you would like to be contacted with a summary of the research findings, please tick this box.

Thank you again for your vital help with this research.

Catherine Graves

Ee14cg@leeds.ac.uk

Control survey

[[as the pre-test survey above, minus the intervention only question, and with additional 'Recurring Pro-environmental Behaviour Scale' (REBS) (adapted from Brick, Sherman and Kim, 2017)]]