

# Design for the change before behaviour

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# Abstract

Local governments around the world are spending millions to monitor, analyse and visualise air pollution using smart technologies; however, data and visualisations can only be effective if equally strong actions are taken to improve air quality. This thesis critically analyses the often reductionist technological approaches to, and narratives of, smart cities which are aimed at addressing air pollution and mitigating the effects of climate change, with a focus on two main areas. First, it offers evidence-based practical alternatives to these approaches and suggests how future work in this field might expand this narrow design space. Second, it examines and applies in practice a number of social psychology and behaviour change insights, to understand the most appropriate ways of helping people transition to zero- and low-pollution lifestyles through the design of new technology enablers and through collective action.

Mitigation-focused actions will not be enough to address the complexity and severity of the air pollution challenge alone. This enquiry focuses on using design research practices to develop a set of technology experiments or enablers that could shift the focus from pollution monitoring (measuring pollution that has already been produced) to pollution prevention (pre-empting pollution before it is produced). Current sensing and data visualisation projects in the fields of design for behaviour change, human-computer interaction (HCI) and persuasive technologies often either focus on 1) the behaviour while it is being performed or 2) reporting about the behaviour that has already been performed. The prevention-focused technology design experiments in this PhD set out to understand the moment or space right before a behaviour occurs. Through this enquiry, it is argued that a technology enabler can be designed to address this moment or space and intervene to gain time for and enable a deliberate pause between people's 'auto-pilot' behaviours and more effortful considerations of their day-to-day activities; their usual behaviour can be disrupted and shifted to a new behaviour. But this shift is only possible if 1) the right advice is designed and delivered at 2) the right time with 3) the right frequency, and in 4) the right place and context. Moreover, while it is difficult to identify and address all the reasons for the discrepancy between people's values and intentions and their actual behaviours or actions, this thesis also argues that technology enablers could help in efforts of closing the 'value-action' gap and deliver feedback to a space where it was previously missing.

In alignment with these findings, and because of their widespread use in people's homes, this thesis tests current home artificial intelligence (AI) assistants and applies them to deliver a set of

behavioural and psychological insights in practice. The four design experiments described in this thesis offer new socially and environmentally minded adaptations to these assistants. They shed light on potentially more meaningful types of interactions with these technologies, demonstrating how they could engender a more proactive role for citizens in enabling positive social and environmental change.

In the first two experiments, a new skill is applied to an existing AI assistant technology. In the second, the author takes on the role of an AI assistant, to better understand her participants' view on air pollution, the climate crisis and sustainability in general: what they value and prioritise in their daily lives, social practices and behaviours, and what activities they might be willing to change. In the third experiment, a new design method and custom-built, digital assistant or social companion known as Climate Pal (CP) is developed with a group of participants. This demonstrates the potential role of home assistant technologies to increase the degree of participation in pre-empting pollution in cities and help people articulate their own agency in complex environmental matters. The final experiment offers a new alternative to further increasing people's agency by connecting them through a network of home assistant devices to a group of like-minded people, so they could enable and take collective social and environmental action together. This new approach tests whether the social aspect of the intervention makes participants' engagement and the changes in their behaviour more durable than if the intervention were to be focused solely on individual action. The outcomes point to the need for new technology designs that account for and support participants' core values and desire for social connection and belongingness, for being challenged by, and learning from, others; for doing good for other people; working towards a shared goal; and becoming part of something greater than themselves.

This PhD sets out to design technologies that increase people's agency in taking meaningful social and environmental action, individually as well as collectively. The aim of this is to overcome the perception that small changes by individuals are somewhat futile when it comes to the inaction of a whole world of other people. The four design research experiments result in a new set of technology design principles for others to use. By moving beyond passive observation of pollution and energy use through air quality sensing technologies, clean air route-finder apps and smart metres, this set of design principles aims to enhance people's agency and establishes a new, prevention-focused technology design approach that can help reduce polluting and energy-intensive behaviours before they even happen. The work has value for those designing for

agency and behaviour change, as well as governments and local authorities interested in improving pollution, and for designers involved in developing emerging AI technologies and improving human-computer interaction.

## Author's Declaration

I declare that this thesis was written by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification.



# Acknowledgements

The ideas in this thesis have taken shape over many years through conversations and exchanges with numerous people. I would like to thank the following people in particular for their support and help throughout the development of this project.

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Over the last one and a half years of this PhD I started working as a Lead Advisor at Design Council's Architecture and Built Environment team. I feel lucky to have met and be able to work with such an incredible group of people who also became my friends. Without their professional and emotional support, I could have never finished this thesis.

There are many others who had crucial role in me completing this doctoral degree. I couldn't have finished my studies without my friend, Fuli (Jozsef Fulop) who is the Rector of my former university, Moholy-Nagy University of Art and Design. He had a crucial role in starting this PhD at RCA back in 2014, which I will never forget. And also, Gabor Ebli for all the "panicked" wanders of how I could start a life abroad – throughout the last year of my master's degree. I would also like to say special thanks to Szabi (Adam Somlai-Fischer) for being so supportive and believing in me since we met. Working with Szabi at Kitchen Budapest Innovation Lab in 2007 was really the start of the nine-year journey that brought me to this moment in life.

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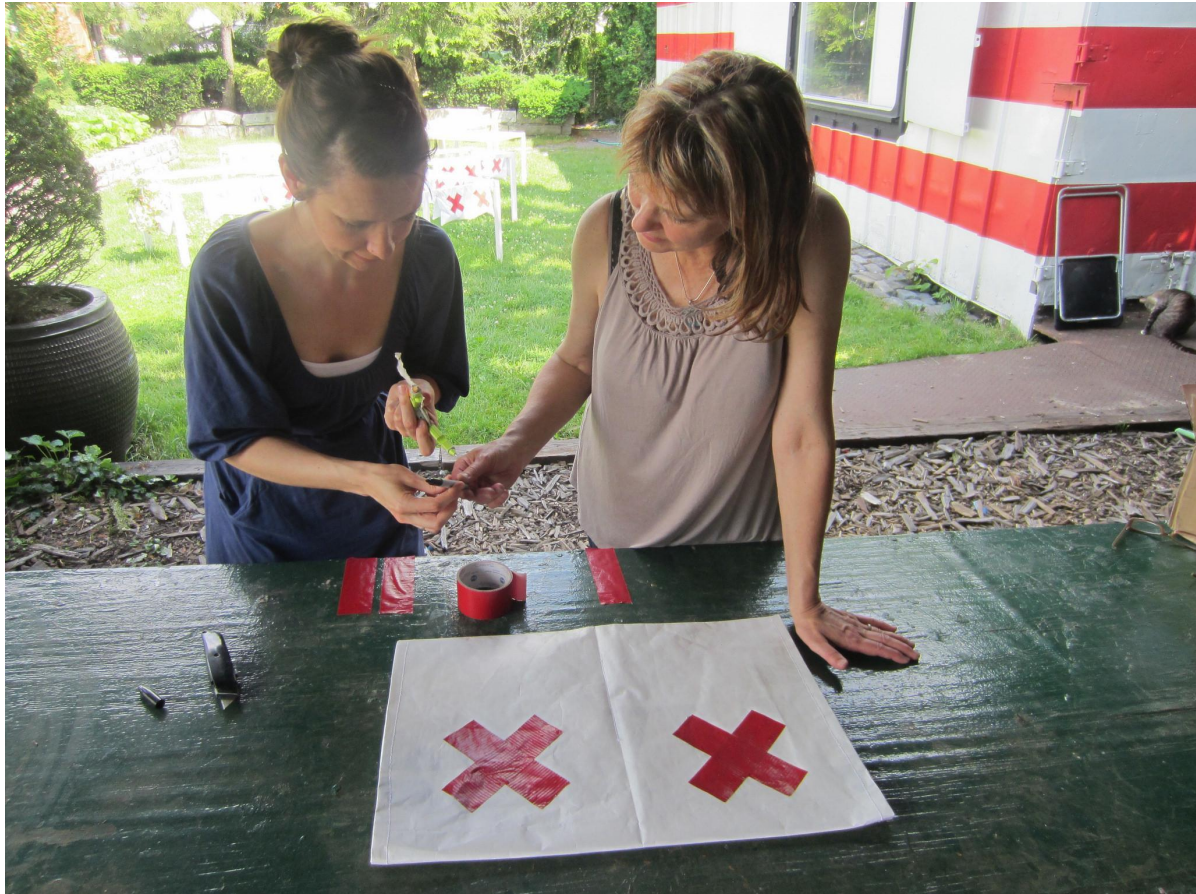
# Motivation

Borrowing insights from a variety of disciplines, my projects explore the effects of human activity on the environment and attempt to address the complex social, political and economic factors that engender and reinforce pollution-producing practices and behaviours in cities.

With a background in strategic design, behavioural science and environmental health, I have more than a decade of experience delivering projects in the public, private, and third sectors. I have designed, led and managed a variety of projects in North America, Asia and Europe - working in organisations ranging from small start-ups and individual communities to large corporations and city governments.

In my work, I use air pollution and climate change as ‘trojan horses’ to observe and better understand different barriers to individual and systems change. Improving air quality, for example, will require an understanding of how air pollution is currently produced and how it’s made ‘invisible’ or more salient through current political, economic and technological narratives and opposing interests.

From 2007 to 2014, I worked as an installation and technology designer with a focus on environmental and political issues – applying participatory and speculative design methods. Much of this work was intended to generate community engagement and grassroots action about invisible environmental pollution and low carbon social innovation. After seven years, however, I started to doubt the effectiveness of this approach. Whilst my temporary installations, speculative design pieces and art interventions did generate interest, they failed to achieve the sustained civic and political engagement and action that I knew would be necessary to address complex, long-term problems, such as air pollution and climate change.



*Figure 1. AgBag Installation: “Farmacy uses an existing medical model—a clinical trial—to directly involve people in re-imagining the health of their urban environment. It is a public experiment, a tool to test and develop scalable urban agriculture. At each of the different clinical trial sites, in which AgBag’s<sup>1</sup> are installed, the growth responses of plants are monitored, and air quality improvements are evaluated.” Photo © Natalie Jeremijenko*

I worked with various artists, design practitioners and community groups that aimed to raise awareness about pollution by making the invisible visible. People like artist and designer Natalie Jeremijenko, who built a mussel-choir (Jeremijenko, 2012) to address the qualities of water and its invisible pollutants through performing and singing.

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<sup>1</sup>Curating Cities (2011): “Agbags are growing platforms created out of Tyvek—a high tensile spun olefin material—and filled with soil, growing nutrients and a range of edibles. Agbags can be suspended over existing architectural features—railings, double-hung windows, parapets—as they are counterbalanced, which allows for easy instalment into urban spaces such as balconies.” Available at: <http://eco-publicart.org/xclinic-farmacy/>



Figure 2: Natalie Jeremijenko's *Mussel Choir* – An art installation that uses marine organisms to collect data about and represent real-time water quality.<sup>2</sup> Photo © Natalie Jeremijenko

And artist Fran Gallardo, who cooked and tested jam from blackberries (Arts Catalyst, 2014) grown from the once-contaminated soil of Leigh-on-Sea. I also exhibited my work alongside the artist's book project by Helen Evans and Heiko Hansen, which took the form of an anthology focused on the perception of man-made clouds in past and contemporary culture (Pollinaria, 2009). Inspired by this work, I looked for others working in this space. I found artist and professor John Sabraw, who used toxic runoff found in the Ohio River region to produce his own DIY pigments (Gambino, 2013). I also learned about Japanese communities that were experimenting with seed planting to 'visualise' the invisible, local radiation-levels coming from the Fukushima nuclear power plant (Gill, 2015). Based on this body of work, I came to believe that by "making the invisible visible" artists and designers could encourage sustained civic and political action - and this belief formed the hypothesis of my initial PhD research proposal. Through my research, however, I have since learned that making an issue more visible is often

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<sup>2</sup>Melbourne Mussel Choir, Carbon Arts: "One mussel can filter as much as 6-9 litres of water/ hour. By instrumenting mussels with hall effect sensors, which indicate the opening and closing of their shells, and by giving them each a voice, converting the data into sound, the artwork uses the behavior of the organisms themselves as a biologically meaningful measure of pollutant exposure in order to produce a public spectacle." Available at: <http://www.carbonarts.org/projects/melbourne-mussel-choir/>



not enough to effect change (see Chapter 2 for a detailed discussion).

Analysing the projects above and others like them, I found only a few cases that achieved sustained public and political engagement and had a meaningful impact on pollution. Most of these projects never went beyond the exhibition or gallery space.

Even when pollution is visible and those affected are aware of its harmful effects, enacting change is often very difficult. I experienced this first-hand while working with communities that were being directly affected by pollution. Though they could ‘see’ the pollution around them and were eager to do something about it, they had limited power and agency to do so. Paradoxically, my work to highlight pollution and its effects mostly just increased the anxiety or disillusionment of those affected.



*Figure 3. Hulla Hoop: Long Island City residents help us revitalise the park and improve soil quality by using hula hoops that double as wildflower seed distributors. Photo © Natalie Jeremijenko*

Searching for another approach, I sought out experts who might better understand systems change and the ways in which these communities could be supported to actually improve their health. I gained invaluable insights from personal conversations with experts including Professor Frank Kelly (the Director of the Environmental Research Group at King’s College); Kevin Anderson (the Deputy Director of the Tyndall Centre for Climate Change Research); and Sir David King (the Former Special Representative for Climate Change to the UK Government).

At the beginning of my PhD studies, I was looking for a way to learn more about systems change and work with city leaders and local authorities to better understand approaches to reducing pollution and mitigating climate change at a city scale. In 2015, I came across the Future Cities Catapult - a UK government funded centre for the advancement of urban innovation. And later that year I was hired by the Catapult as a part-time design researcher, to explore a broad range of urban issues, including smart city technologies, sustainable mobility, energy systems, and air quality. Based on my prior research and knowledge, I became the Catapult's in-house advisor on air pollution and low-carbon lifestyles, a position I held for more than three years. In 2018, I joined the Design Council as a Lead Advisor of the Architecture and Built Environment (aka CABE) team, which has a remit to understand and support the value of design in the built environment.

Urban liveability for me is about fairness and equal opportunities measured by the wellbeing of those who are the most vulnerable. I believe technologies could provide alternative discourses and practices, instead of simply reproducing already existing structures, practices and norms in society. However, current technological narratives often support and reproduce current ways of living and thinking.

I arrived at this practice-led PhD in 2014 as someone who tries to promote change as an environmental activist. But I have since been approaching it as someone who also tries to make a difference as a designer.

I started this PhD to challenge assumptions that have long been dominant in smart technology design aimed at monitoring and improving air quality and to apply design research to behaviour change to reduce pollution in cities.

While I was trying to understand where to start this process, I was reminded of a conversation with my late supervisor, Ranulph Glanville. Over the course of the PhD there were a number of changes to the title, the first title started out something like this: 'I've got the power!' - How can we use our creative power and technological opportunities to address the complex social and environmental challenges we face in the C21st?



Ranulph encouraged me to challenge the title. “Who is the ‘we?’” he asked. Through this practice-led PhD and my day-to-day work, I have spent the last four years trying to figure it out. I now have a better understanding of who the ‘we’ is, and I hope some of my findings will be valuable to those who are interested in similar questions.

## Chapter 1. Arriving at this topic

With more people living in cities than ever before, urban air quality has become a serious concern. Pollution is especially damaging to the health of children. Exposure to vehicular air pollution during pregnancy, infancy or childhood has been associated with delays in cognitive development (Woodward et al., 2015; Sunyer et al., 2015; Pujol et al., 2016). Numerous studies (Gauderman et al., 2004; Eminton, 2012; Marino et al., 2015) suggest that air pollution has adverse effects on lung function and development. While shortening life-expectancies, this exposure makes people more likely to suffer from increased rates of respiratory illnesses, COPD, strokes, ischaemic heart disease and lung cancer (LSHTM, 2018).

Socioeconomic status regarding invisible environmental pollutants – with their complex socio-spatial patterns – also play a significant role in people’s health. As Tonkiss (2015) explains “one of the crudest inequities in contemporary cities is between those whose lifestyles produce environmental harms and those whose livelihoods and living situations make them most vulnerable to these harms.”

While being harmful to human health, pollution not only reduces quality of life but also productivity. In 2013 the World Bank (The World Bank, 2016) reported that premature deaths due to air pollution “cost the global economy about \$225 billion in lost labour income” and “the aggregate cost of premature deaths was more than US\$5 trillion worldwide.”

Given this worrying information, what can be done?

### 1.1 Ways of addressing air pollution in cities

Achieving a transition to low-pollution<sup>3</sup> cities will require both top-down and bottom-up actions.

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<sup>3</sup>In this thesis specifically, I am referring to low-carbon lifestyles which enable the reduction of carbon emissions and other greenhouse gases (e.g. ozone, methane, nitrous oxide) and low-pollution lifestyles those that also enable the reduction of air pollutants (e.g. particulate matter – PM10, PM2.5 and PM0.1, ozone, nitrogen dioxide, carbon monoxide, sulphur dioxide). There is an important difference between the two; however, the two are also interrelated, as some air pollutants are also greenhouse gases. When carbon dioxide concentration in the atmosphere exceeds a healthy limit, carbon dioxide become polluting. Within this thesis, ‘low-pollution’ will refer to the reduction of both air pollutants and greenhouse gases. As Swedish climate activist, Greta Thunberg argues in her speech at the World Economic Forum in Davos, Switzerland, “we don’t need net zero, we need real zero” and that a low-carbon transition and economy will not be enough to address the current crisis, this thesis will not discuss real zero and zero carbon (where no carbon is produced in the first place) and carbon negative economies in detail, even if these are the most important goals that need to be achieved in any given sector, discipline and behaviour. Many of the actions, behaviours and policies, however, that are studied in this PhD align with and cover these terms. In this

According to the latest estimates of the European Commission (Scruggs, 2018) “84 percent of the world's population, or almost 6.4 billion people [already] live in urban areas”, and therefore the most significant portion of the human activities that lead to local air pollution and global climate change are concentrated in cities. This is also the reason why this thesis mainly focuses on cities, instead of rural areas. Cities have been deliberately chosen, as that is where the biggest number of people exposed to and impacted by pollution.

Outdoor air pollution in cities is mainly produced by the burning of fossil fuels for power generation, heating and transportation. In parallel to urban air pollution, Bulkeley et al. (2011, Preface) explain that “current societies [also] face unprecedented risks and challenges connected to climate change”. They argue that “addressing [these challenges] will require fundamental transformations in the infrastructures that sustain everyday life, such as those relating to energy, water, waste and mobility” (ibid.). The authors emphasise that transitioning to a “low carbon future” can only be achieved by a large-scale reconfiguration of the way “societies produce and use energy” (ibid.). They go on to describe that economic and social activities that are the sources of greenhouse gas emissions are [mostly] concentrated in urban areas, cities will be crucial in enabling this transition (ibid.).

As Betsill (2001, p.394) notes, “municipal governments [also] have considerable authority over land-use planning and waste management and can play an important role in transportation issues and energy consumption, all of which have implications for greenhouse gas (GHG) emissions”. She explains that for cities moving “from political rhetoric to policy action” is challenging because of different institutional barriers (ibid., p.399). She goes on to describe that the way city governments are set up there is often “no institutional home for climate change policy making” and cities often lack the administrative capacity or technical knowledge to “develop local policies and programmes” for controlling, monitoring and analysing local GHG emissions (ibid.). The efforts towards transition are frequently inhibited by a lack of capacity and by political tensions over the continuation of urban development and economic growth.

Moloney and Horne (2015, pp.2438-2439) argue that a large-scale transition will need “a coordinated and integrated approach to policy and governance” and “an alignment of goals

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thesis, I decided to use the word ‘low’ to be able to include and foster even the smallest changes to reduce air pollution and address the climate crisis.

across land-use, transport and energy infrastructure planning, and in the design and retrofit of buildings and precincts”. Instead of solely relying on unconnected, local actions, they further argue that a more coordinated set of actions and policy responses across a range of governing scales will be essential for systems change (ibid., p.2438).

Similarly to Moloney and Horne, Hodson et al. (2013, p.1404) suggest that what is:

“required is a fundamental transformation of socio-technical infrastructure systems—including ‘new’ forms of energy technology, but also new regulatory frameworks, patterns of consumption, governance frameworks, spatial organisation and so on...”

To understand these urban transitions, the authors argue that it is crucial to examine the range of social interests involved in energy systems (by policy-makers, utilities, regulators, consumers, entrepreneurs, etc.) with the range of expectations and motivations of different “state and non-state actors” (ibid., p.1404); and the politics of whose preferences and interests are more powerful and what the consequences are of those for “urban transitions” (Hodson and Marvin, 2012, p.422).

Building on the idea that the change that will be necessary to deliver on key emission targets can’t be accomplished by “technical fixes or low-level changes in behaviour” alone (Hodson et al., 2013, p.1404) – this enquiry explores not only the current technological but also the political and social responses to air pollution and climate change (Bulkeley et al., 2011, Abstract). In particular it focuses on air pollution sensing – and how design research could be applied to re-imagine the monitoring process itself and to behaviour change in reducing pollution in cities.

In a smart city many ‘technical fixes’ are offered to address air pollution. Equipping cities with measuring instruments (Air Monitors, 2018; EU Science Hub, 2017; CityLab, 2018) has become a popular way for local governments and community groups to understand and measure environmental health risks, such as noise, heat and air pollution. In cities around the world – and particularly in the UK (Air Monitors, 2018; DEFRA, 2018); Europe (EU Science Hub, 2017); India (Joshi, 2016) and the United States (Plautz, 2018), to name but a few – air quality sensor networks have been deployed on the basis that better, more granular data will help inform policy-making and legislation aimed at improving air pollution.

In parallel to government and intergovernmental initiatives (London Air, 2018; EU Science Hub, 2017; DEFRA, 2018), the citizen-sensing movement (CitiSense, 2012; Citizen Sense, 2013; iScape, 2017; Making Sense, 2017) and private sensor-vendors specialising in smart cities (Smart Citizen, 2018; Purple Air, 2016; CleanSpace, 2018; Aclima, 2018; Kanowitz, 2016) have been developing sensing applications of their own. While the latter are mostly commercially driven, the former aim to democratise the collection of environmental data and thereby engage citizens in environmental health issues directly. As Gabrys (2015) describes it:

“citizen sensing projects intend to democratise the collection and use of environmental data, and in the process enable public engagement with environmental issues, such as air pollution”.

## 1.2 Equipping the city with measuring instruments

There are numerous smart cities and Internet of Things (IoT) projects underway in cities around the world, involving huge sums of capital and resources. According to a 2016 Tech Pro Research report “the smart city industry is projected to be a \$400 billion market by 2020, with 600 cities worldwide” (Tech Pro Research, 2016).

As Maddox (2018) explains, “smart cities practitioners advocate the digital transformation of our cities to improve environmental, financial, and social aspects of urban life” and she defines a smart city development as “the use of smart initiatives combined to leverage technology investments across an entire city”. Much of this definition is based on the idea of increasing control through better intelligence.

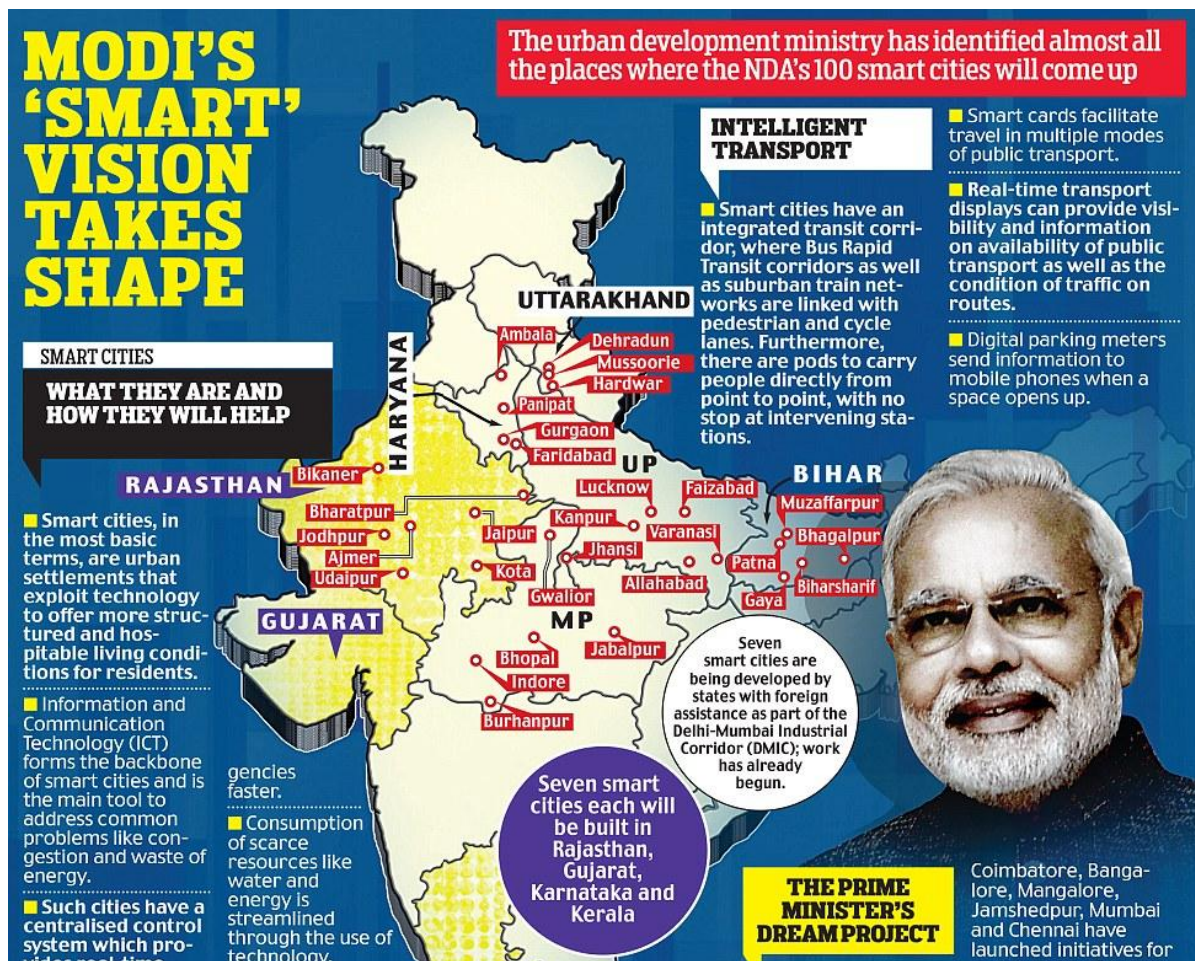


Figure 4. "Smart cities are the catchphrase as Prime Minister Narendra Modi's government lays the groundwork for his ambitious program aimed at setting up 100 such urban settlements nationwide." Photo @ Daily Mail

As Fantini van Ditmar (2016, p.21) explains about the Internet of Things:

"The IoT can be defined as a system in which everyday objects are digitally identifiable and programmable, and connected to the Internet. These connected objects are able to send (and often, but not always, receive) data, connect to other devices, and respond to the algorithms that govern them, often acting without human intervention."

According to the global consultancy BCG (2017) by 2020 spending on Internet of Things (IoT) technologies will reach \$250 billion.

<sup>4</sup>Vikram, K. (2014). Modi's vision of 'smart cities' takes shape as government commits to delivering first three hubs by 2019. Daily Mail. Available at: <https://www.dailymail.co.uk/indiahome/indianews/article-2738057/Modis-vision-smart-cities-takes-shape-government-zeroes-scores-sites-country.html>

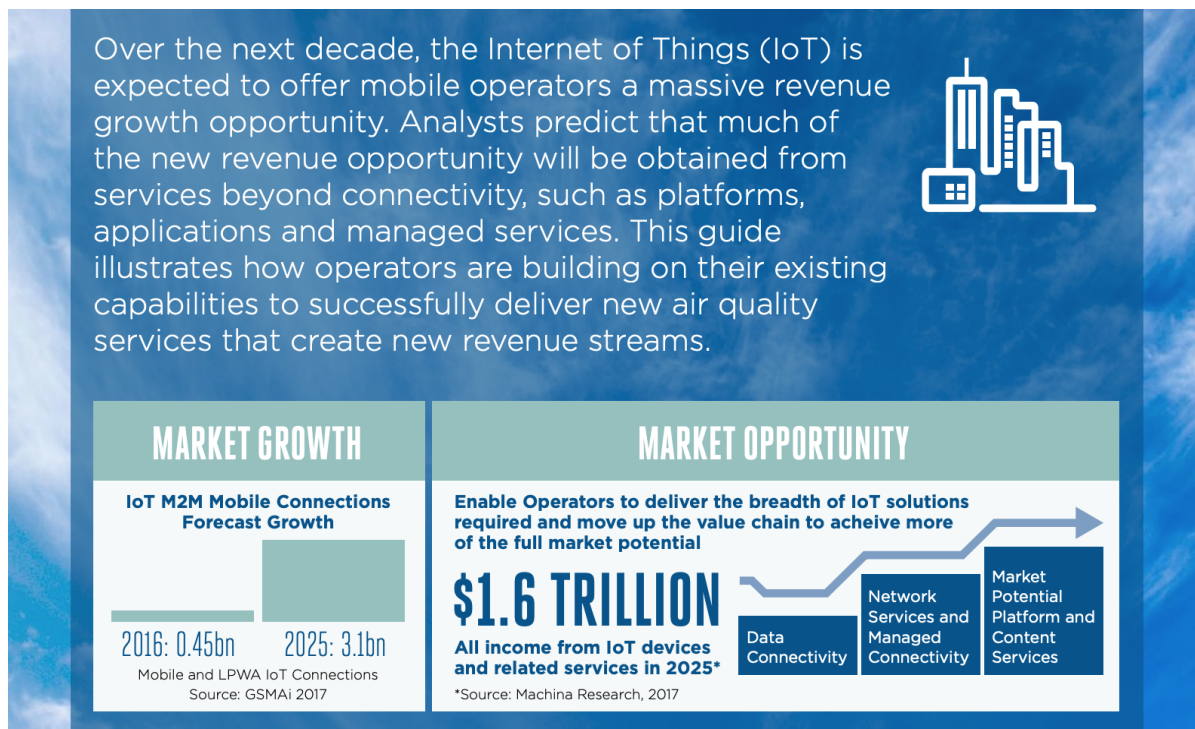


Figure 5. A screenshot of GSMA's market research from 2018

Specifically looking at air quality and sensing technologies, Global System for Mobile Communications (GSMA, 2018, p.4) notes that there are “significant commercial opportunities” in the air quality monitoring and control market and forecasts that the “global air quality monitoring and control market [will be] worth around \$20BN in 2021”. While KTN (2017) suggests that:

“sensing devices for air quality monitoring [specifically] were worth \$3.4b globally in 2015, and will continue to grow at a rapid rate, and expected to reach \$5.64bn by 2021.”

There has also been significant funding available in the European Union (European Commission, 2018) to better understand and improve air quality, with projects such as: Making Sense, Citizen Sense, OrganiCity, CLAIRCITY, iScape and ICARUS, to name but a few.



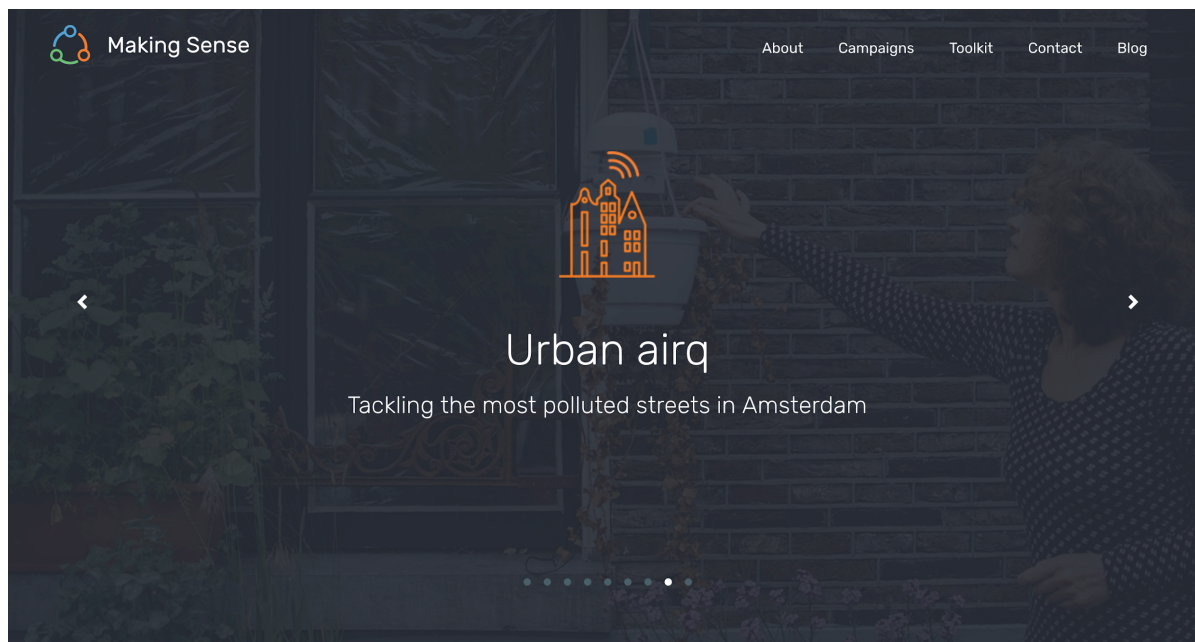


Figure 6. A screenshot of the website of Making Sense: “A new approach to citizen science: Co-creating technology for change with concerned communities.”<sup>5</sup>

Given the enormous outlay for air quality sensors, it seems crucial to better understand the ways in which these sensing technologies are designed, the value of sensing and the steps that need to be taken from monitoring air pollution to improving air quality.

### 1.3 Understanding the value of sensing

Sensing is a critical step towards improving pollution or assessing environmental risk. To put it simply, before local authorities and governments can make a plan to take action about air or other environmental pollution, they first need to know whether they have a problem in the first place. With a better picture of the levels and sources of pollution, they can then calculate and balance the cost of health impacts with the cost of interventions that could improve the issue. Most importantly, all of these actions need to be backed up by accurate data.

Carbon dioxide sensing, for example, has provided critical evidence about global warming. At the Big Island, Hawaii, Mauna Loa Observatory (MLO) is a “premier atmospheric research facility that has been continuously monitoring and collecting data related to atmospheric change”

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<sup>5</sup>Making Sense’s website. Available at: <http://making-sense.eu/about/>



(ESRL, 2018). The data collected here since the late 1950's has been instrumental in recording growing carbon dioxide levels and global warming.

The Environment Agency's monthly water situation report (Environment Agency, 2018) for England – with current status and future forecast of water availability – is another example of the value of environmental sensors. An example of collaboration between the Environmental Agency, Met Office, Centre for Ecology and Hydrology and the British Geological Survey demonstrates how models for future forecasting and sensors measuring water (including rainfall, river level, river flow, groundwater levels, reservoir levels) can be used to help monitor and report water availability in the UK, which is particularly important during periods of flooding or droughts (GaugeMap, 2018; River and sea levels in England, 2018; BGS Groundwater levels, 2018; National River Flow Archive, 2015).

Sensing can also provide evidence for communities affected by pollution to challenge the authority of governments and industries that produce false or misleading information. There are numerous examples of sensing being used in support of community-led initiatives to enable change, not only on air quality monitoring but on sustained engagement with air and other environmental pollutants. Following the Fukushima Daiichi nuclear disaster in March 2011, Pachube (now Xively) enabled widespread public discussion through the crowdsourcing of real-time radiation data (Haque, 2012). Residents in Cuddalore District of the south Indian state of Tamil Nadu, are forming “Bucket Brigades” to measure their community's air quality and fight for healthier environments against the impacts of the State Industries Promotion Corporation of Tamilnadu Ltd (SIPCOT). SIPCOT was established in 1971 to develop industrial growth in Tamilnadu (SIPCOT, 2018). A new partnership has helped people in six villages get to the root of their severe health problems. As Kushik and Dunn (2004) notes:

“villagers have teamed up with the Other Media, consumer group FEDCOT and Global Community Monitor (GCM) to begin gathering evidence and building a case to force companies to comply with pollution laws.”

Communities in India and across the U.S. use the Bucket to collect and test air samples and use the data to advocate for stricter environmental regulations (Grassroots Change, 2014).

A series of interviews were conducted during this research with Professor Frank Kelly, the Director of Environmental Research Group (see summary of our conversations in Appendix 1).

ERG has been testing various air quality sensors for several years. During my visits to ERG Professor Frank Kelly explained how important it is for cities to have accurate data and high-quality equipment – which they either own or rent – to understand their particular pollution challenges and required actions. When investing in high quality monitoring stations is too costly, local authorities can hire mobile equipment that can be moved around to collect data in a number of locations. This is a practical and economic alternative to purchasing high-value fixed equipment or costly and hard-to-maintain low quality sensor-networks.

He also explained how current low-quality sensor networks do not provide data that is accurate enough for developing further policy actions – though they can be a useful way to raise awareness amongst the general public.

In summary, air quality data and other environmental data can allow cities and citizens to evaluate the efficacy of their interventions and help regulators enforce current legislation, but this thesis also argues that sensing, awareness raising, and citizen engagement alone are not enough when it comes to addressing the complexity of and sources of pollution.

Before investing in and deploying sensor networks, cities, technology vendors, designers and activists should be aware of how costly and time-consuming it can be to maintain these networks – such as data analytics, calibration, and battery life.

Though high-and low-cost sensors can be both useful for raising awareness about air pollution and make more informed decisions, it's important to emphasise and understand the steps needed to move from 'monitoring air pollution' to actually 'improving air quality' (Galik, 2017). Ideally, data would be produced in the service of a hypothesis or decision and not just for the sake of data spectatorship. If data is being produced in order to decide between two courses of action, then evaluation can be undertaken to decide which action was more impactful.

## 1.4 Understanding the assumptions embedded in air quality sensing technologies

From a few of the hundreds of applications currently available on the market, a variety of air sensing infrastructures, their specific uses and applications have been studied during this research (CleanSpace, 2018; Smart Citizen, 2018; Air Quality Egg, 2018; AirSensa, 2018). This was

followed by a thorough investigation looking at the different marketing narratives of a variety of technology vendors and EU funded projects supporting the monitoring and visualisation of air pollution (e.g. CLAir-City, Making Sense and iScape).

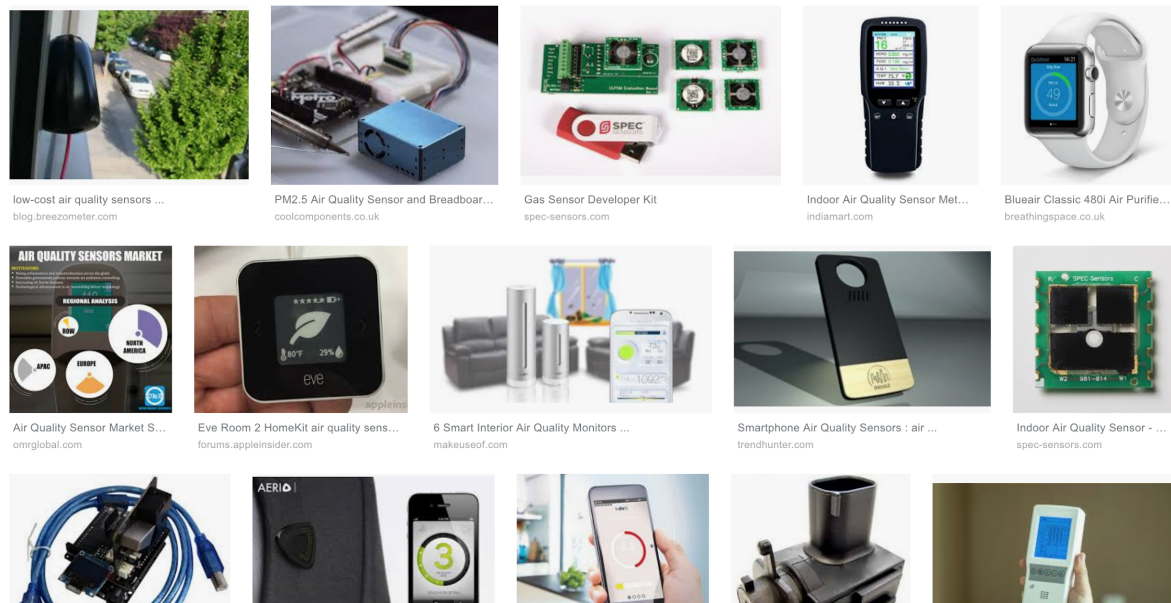


Figure 7. A Google snapshot of different air quality sensing applications available on the market in 2019

By combining the development of sensing technologies and community engagement, all too often these interventions simply confirm the fact that the air is polluted – while citizens and local authorities become increasingly disillusioned by the fact that their air remained just as polluted as ever.

The frustration caused by the size of financial investments – where sensing devices for air quality monitoring are expected to reach \$5.64bn by 2021 (GSMA, 2018; KTN, 2017) – and the lack of evidence and action on improving air quality in return inspired this thesis.

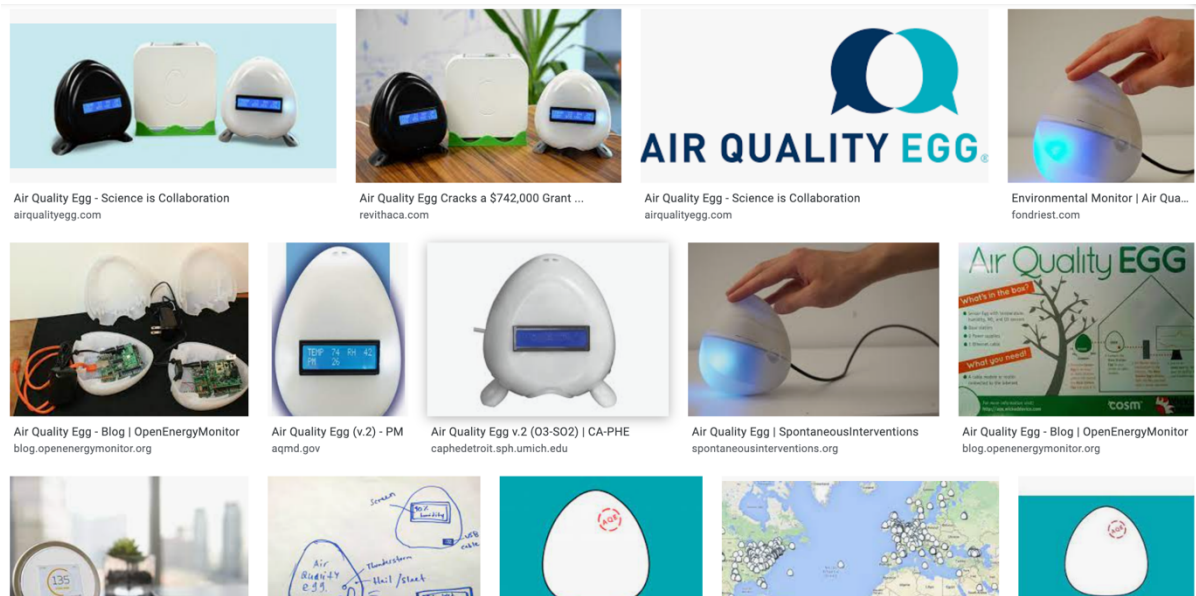


Figure 8. A Google snapshot of Air Quality Egg: “An open-source hardware Internet of Things platform and hobbyist device for crowdsourced citizen monitoring of airborne pollutants” (Air Quality Egg, 2019)

While often ignoring the already well-established evidence of how to actually improve air quality (Fuller, 2019; Galik, 2018a; Galik, 2018b; Lurmann, 2015; China Daily, 2014; Copenhagenize, 2008), a frequent argument in smart cities is that we still need more evidence and even more granular data to be able to manage pollution. It seems as though after we’ve measured pollution, we keep forgetting to manage it through stringent environmental regulation.

Even if with the best intentions, there is often a knowledge gap between what these technologies promise and what they deliver. Air Sensa and Smart Citizen are amongst dozens of those examples (CleanSpace, 2018; Smart Citizen, 2018; Air Quality Egg, 2018; AirSensa, 2018) that claim to improve people’s lives through their technology or allude to the frequent narrative that information provided to the public will address and/or lead to improvement in air quality.

Looking through their projects, news feeds and websites, it is often hard to find evidence that supports their claims in regard to improved air quality. They do not necessary detail either or help people better understand the steps needed from monitoring air pollution to improving air quality.

Air Sensa (2019), for example, describes the following on their website:

Our mission is to generate the data needed to enable individuals, industry and government authorities to make informed choices. The only real data available today is produced by governments for statutory reporting; however, that data is based on modelling from very few measurement points and, as a consequence, is not useful for real-time or accurate determination of harmful pollutants. It is also therefore not useful for addressing the harmful health impacts and suffering that air pollution causes today. We can't manage what we don't measure, so the challenge is to generate much better, more localised data. AirSensa meets that challenge, improving the lives of millions around the world.

Figure 9. A screenshot of Air Sensa's 'About' page of their website

On their 'About' page, they also note:

“AirSensa was created as a commercial organisation in 2018 to focus on a simple mission – to create accurate hyper-local air pollution data, and therefore to address the enormous health and economic impacts of poor air quality, in every city in the world.”

While Smart Citizen (2019) explains:

“The project uses open source technologies such as Arduino to enable ordinary citizens to gather information on their environment and make it available to the public on the Smart Citizen platform.”

Building on frequent narratives, sensing applications seem to share the following argument and research interest:

1. To better understand the causes and effects of air pollution (GSMA, 2018, p.3.; Khan, 2019; AirSensa, 2018) and enable cultural and political change, more evidence is needed;
2. To provide that evidence, more sensors and more accurate data are needed (GSMA, 2018, p.3)<sup>6</sup>;
3. To achieve sustained civic and political action, pollution needs to become more visible. We need to “make the invisible visible” (Invisible Dust, 2019).

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<sup>6</sup>“[It is] difficult for citizens to understand the levels of pollution they experience in their daily lives, as the monitoring data is not available in real time and is very sparse.” (GSMA, 2018)

To further develop the argument of this thesis, it's crucial to study and better understand these narratives, and especially the underlying assumptions and claims that are currently nested in them. Instead of merely increasing the quantity of sensing networks and the granularity of air pollution, promoting, supporting and implementing the decisions that need to be made to improve air quality would have a more beneficial social, environmental and economic impact in the long run.

The analysed sensing applications have challenges to bridge the gap between awareness and action. Often, these interventions do not necessarily help people to better understand the complexity of the context in which the air pollution data is gathered either. Many also simplify how pollution is produced and understate the effects of different cultural and political contexts. Few take into consideration how politics, economic interests and public narratives can determine how cities and citizens respond to pollution (Gill, 2015; Kuchinskaya, 2014; Moloney & Horne, 2015; Hodson et al., 2012; Bulkeley et al., 2011; Ockwell et al., 2009).

#### 1.4.1 If only we had more evidence...

A frequent argument in air quality sensing is that “you can't manage what you don't measure” (AirSensa, 2019; BuggyAir, 2018; University of Cambridge, 2015). That to better understand the causes and effects of air pollution (GSMA, 2018, p.3.; Khan, 2019; AirSensa, 2018) and enable cultural and political change, more evidence is needed. Contrary to this argument, there are a number of cities and urban areas – such as Copenhagen, Lanzhou City and Southern California – that have already been able to reduce air pollution and enable positive behaviour changes through a combination of citizen engagement, infrastructural and systems change, and environmental regulation.

## 117 Safer Intersections in Copenhagen

The City of Copenhagen announced yesterday that 117 intersections throughout the city will be altered so that the stop line for cars and trucks will be pulled back by a minimum of 5 metres.

Vehicles turning right and hitting bikes is the most common form of accident for cyclists so Copenhageners can now look forward to increased safety around the city.



Here's a photo of the main intersection next to the City Hall Square in Copenhagen, taken from the City Hall tower. Hans Christian Andersen Boulevard and Vesterbrogade.

*Figure 10. A screenshot from a blog on Copenhagenize demonstrating how Copenhagen has made their intersections safer for cycling<sup>7</sup>*

Copenhagen has been systematically prioritising walking and cycling by introducing wider, safer and separated cycle lanes and safer intersections (Copenhagenize, 2008). Vehicles turning right and hitting bikes was the most common form of accident for cyclists, so Copenhageners now have increased safety around the city. Denmark also introduced stronger environmental regulation to reduce pollution from residential wood burning and emissions from shipping. As the Danish Ministry of the Environment and Food (2015) explains “international regulations require ships in the North Sea and Baltic Sea to run on clean fuels with a low content of sulphur”. They further describe that stopping ships from “ignoring the rules and continuing to use illicit fuels”, they have intensified their ship pollution control with an ‘artificial nose’ called the Sniffer (ibid.). Fitted to the Great Belt Bridge, the nose can detect the type of fuel a ship is burning as it sails into the harbour. Since the system was introduced in 2015 the content of sulphur in the air over Denmark has decreased by up to 60%.

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<sup>7</sup>Copenhagenize (2008): 117 Safer Intersections in Copenhagen. Posted: 19 July 2008. Available at: <http://www.copenhagenize.com/2008/07/117-safer-intersections-in-copenhagen.html>

Being the base for heavy chemical industries for years, the capital of northwest China's Gansu Province, Lanzhou City was named the most polluted among provincial capital cities in 2009 (China Daily, 2014). The city had “more than a thousand coal-fired heating boilers, three large thermal power plants and about two hundred thousand civil small boilers in the urban area” (ibid.).

In two years, the city became the exemplar of pollution control. All the heating boilers in the city were replaced with natural gas-fired heating systems, while the power plants were given emission limitations, and residents were ordered to use alternatives to burning coal. The city further reduced coal-generated and industrial emissions and introduced automobile exhaust control to reduce pollution (ibid.).

Lanzhou also suspended two hundred highly polluting companies in winter, closed thirteen polluting companies with excessive capacity and moved seventy-eight industrial enterprises to an industrial park outside the city (ibid.).

Lurmann et al. (2015) argues that “for many cities facing the challenge of reducing air pollution to meet health-based standards, the emission control policies and pollution reduction programmes adopted in southern California should also serve as an example of the potential success of aggressive, comprehensive, and integrated approaches”.

After establishing the evidence for both the short- and long-term effects of pollutants on children's health, regulatory policies introduced between 1994 and 2011 across several communities in southern California decreased average NO<sub>2</sub> by 28% to 53% and PM<sub>2.5</sub> by 13% to 54% (Lurmann et al. 2015, pp.324-35).

Lurmann et al. (2015, p.324) further explain how “policies targeting on-road mobile emissions were the single most important element for observed improvements in the Los Angeles region”. As a result of a holistic approach implemented to bring about emission reductions “across all major pollutants and emissions categories” (ibid.), Southern California has been successfully improving air quality since 1992.

Professor William Gauderman – from the Keck School of Medicine at the University of Southern California – visited the UK in 2017 to present the ways in which Southern California



improved air quality between 1992 and 2014. He was kind enough to share his key findings to support this research and explained some of the major regulatory policies that contributed to Southern California's successful pollution reduction programme. These are summarised in the slides and tables below.

University of Southern California 

**Don't we already know air pollution is bad for us?**



Figure 11. Los Angeles air quality issues in 1948. Slides © Professor William Gauderman

## Well Established

- **Air pollution causes acute (short-term) effects, e.g.**
  - Physician visits
  - Lung function changes
  - Acute symptoms in asthmatics and other susceptible subgroups



Figure 12. Well-established evidence on the impacts of air pollution on human health. Slides © Professor William Gauderman

Regulatory policy	Adoption date
<b>On-road emissions:</b>	
Low-emission vehicle standards for light-duty and medium-duty vehicles (LEV, LEV II)	1990, 1998
Reformulated gasoline	1988, 1990, 1991
On-board diagnostics standards for light-duty vehicles	1985, 1989
Medium-duty and heavy-duty truck gasoline emission standards	1995
Heavy-duty diesel truck engine emissions standards	1998, 2001
Clean diesel fuel requirements	2003
Financial incentives for replacement or retrofit high-polluting vehicles, engines, and equipment (e.g., the Carl Moyer Program)	1998–2012
Cleaner port (drayage) trucks	2007
<b>Off-road emissions:</b>	
Cleaner diesel fuel for oceangoing vessels, harbor craft, and trains	2004, 2008
Reduced port auxiliary engines and incinerator use, hoteling	2007
Cleaner locomotive engines in southern California	1997, 2010
Stationary diesel engines standards for in-use agricultural engines	2007
<b>Stationary point sources:</b>	
NO <sub>x</sub> and SO <sub>x</sub> reductions from Regional Clean Air Incentives Market (RECLAIM)	1994
New source review (NSR)	1990
Source-specific emissions standards	1988–2002
<b>Area sources:</b>	
Low-emission certificate programs for products and equipment	1988–2012
Unpaved and paved road dust control measures	2008
Water heater and small boiler emission standards	1999, 2004

Figure 13. A screenshot from the article of Lurmann et al. on 'Major regulatory policies affecting pollution and emission trends in California', 1985-2012, (Lurmann et al., 2015, p.332)

In the very same week that Professor Gauderman shared his insights on how they successfully improved air quality, a keynote speaker of another air quality conference at the Danish Embassy in London made the following remarks (recorded in personal conference notes):

"I think it's hard to come up with big successful policies [to improve air quality] that work because the evidence base here is very thin. I suspect that this scarcity is due to two factors: first, a lack of big interventions to tackle the problem, and second, the difficulties of objectively assessing intervention outcomes."

Despite all the evidence mentioned above – the argument that we don't know enough about air pollution to improve it remains a key driver to deploy more sensors and gather more data, even in places where there is plenty of evidence available. It frequently comes up as a discussion topic at smart cities conferences, in articles (Ach, 2018; Nichols, 2018) and as a rationale for public projects and investment (Khan, 2019).



Figure 14. A screenshot from the video published in Sadiq Khan's tweet on 19 January 2019: "Children at more than 440 schools in London breathe air that exceeds safe legal pollution levels. We launched the world's most advanced network of air quality monitors to investigate and improve London's toxic air."<sup>8</sup>

#### 1.4.2 If only we had more sensors and accurate data...

The second, frequent argument of air quality sensing applications is that to provide evidence more sensors and more accurate data will need to be deployed and gathered (GSMA, 2018, p.3)<sup>9</sup>. While sensing is crucial (please see Chapter 1. Section 1.3), it is also important to emphasise that sensing technologies are just as vulnerable to political and economic power dynamics as any prior technologies.

Like photographic cameras before them, smart sensing technologies are perceived as the ideal of scientific representation - a phenomenon which Daston and Galison (1992) referred to as "mechanical objectivity". These tools raise the same question that Reiss and Sprenger (2016, p.1)

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<sup>8</sup>Tweet of Sadiq Khan (2019): Available at: <https://twitter.com/MayorofLondon/status/1086584474215899136>

<sup>9</sup>"[It is] difficult for citizens to understand the levels of pollution they experience in their daily lives, as the monitoring data is not available in real time and is very sparse." (GSMA, 2018)

describe as ‘scientific objectivity’, in which “the claims, methods and results of science” and the numbers they show “are not, and should not be influenced by any particular perspectives, value commitments, community bias or personal interests”. As with any data source, however, measuring devices can also be political (Gill, 2015; Kuchinskaya; 2014).

As each of these technologies was designed, they therefore reflect something about their designer, and their designer’s particular worldview. The same way as someone decided on the definition of pollution and what counts to be a ‘healthy’ level of pollution, Haque (2016) points out that:

“Somebody somewhere decided on a definition for optimisation, or a definition of efficiency, or a definition of safety, of risk, of certainty.”

Among so many of those who support the ‘big data’ revolution, Anderson (2008) argues:

“This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behaviour, from linguistics to sociology. Forget taxonomy, ontology and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With enough data, the numbers speak for themselves...”

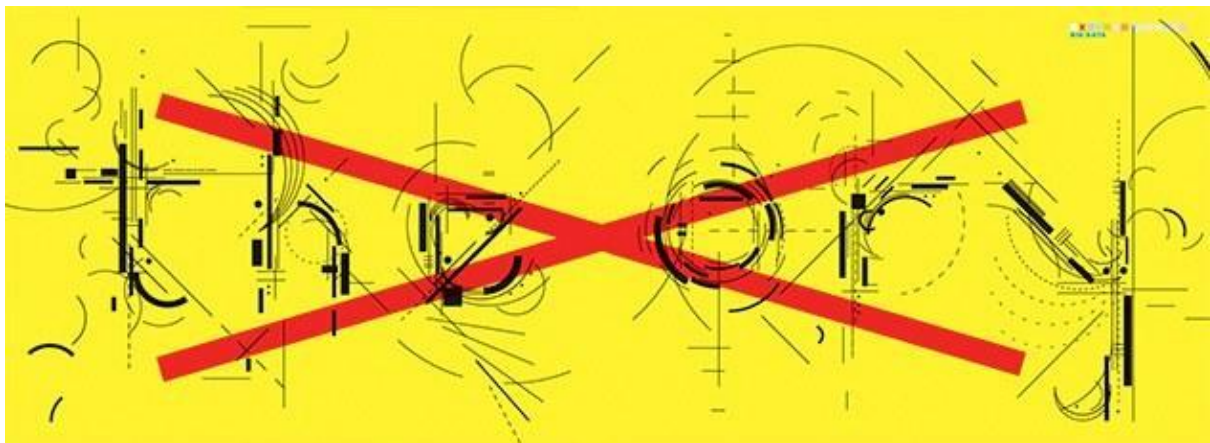


Figure 15. A screenshot of the illustration of Marian Bantjes from the article ‘The end of theory? The Data Deluge Makes the Scientific Method Obsolete’ by Chris Anderson. *Science, Wired Magazine*.<sup>10</sup>

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<sup>10</sup>Anderson, C. (2008). The end of theory? The Data Deluge Makes the Scientific Method Obsolete. Published: 23 June 2008. *Science, Wired*. Available at: <https://www.wired.com/2008/06/pb-theory/>

Contrary to Anderson's argument that the numbers speak for themselves, those who design sensors and interpret the collected data to the public have great power. As Crawford (2013a) refers to this, they are the ones who "give the numbers a voice" and they have a huge impact on how people perceive a situation and behave accordingly (Crawford, 2013a; Kuchinskaya, 2015; Jing, 2015).

Data collection can be manipulated to satisfy political or economic interests. For example, a local authority can get a different air quality reading for a street by moving a sensor a meter higher (Greenfield, 2015). The same is true for radiation sensors, for which high ground versus low ground, the middle or the edge of a road, all massively influence the readings (Gill, 2015). By giving the false impression of 'truth' through mechanical objectivity (Daston & Galison, 1992), monitoring infrastructure and sensor data can have a pernicious influence (Gill, 2015; Greenfield, 2015; Kuchinskaya, 2014; Crawford, 2013a & 2013b).

In other words, for the very reason that pollution is invisible, tools need to be designed to make it visible, and whoever builds these tools – and translates that data to the public through different narratives – has a huge responsibility and in certain cases should be held accountable for their effects. Similarly to radiation, as it is stated in Kuchinskaya's work about Chernobyl's impact on Belarus, in the way that pollution is represented to the public will determine whether its impacts are "observable and publicly visible, or unobservable and therefore publicly nonexistent" (Kuchinskaya, 2014, p.2)

As Figure 15, for example, demonstrates below, the data which is considered to be a "significant concern" in one country, can be described as "good" in another. One can have perfectly calibrated sensors that collect accurate data on air pollution and still the results can be

“translated” or represented differently – depending on the local political or cultural context.



Please note the China, US and Europe all have different color schemes for each grade of air quality and the above color scheme is a simplification designed by the author. 注：中国，美国，欧洲都用不同的颜色来区分空气质量级别。以上的颜色为作者自己简化性地选用。

Figure 16. A screenshot from an article on China Dialogue: air pollution levels that the World Health Organisation considers to be a “significant concern” and for which “immediate actions are recommended” are described as “good” in China <sup>11</sup>

Regarding both data accuracy and visibility of pollution, there are numerous examples of pollution being falsely represented to manipulate public opinion and behaviour in favour of economic or political interests. The Chinese media, for example, affected public perception by misrepresenting pollution as “fog”. And in 2013, the Chinese state broadcaster CCTV and the widely read tabloid the Global Times (published by the Communist Party's official newspaper the People's Daily) said that smog could be strategically valuable to the military, as it could hinder the use of guided missiles. In the same story, they listed other benefits of smog, including helping to unify Chinese people by making them more equal (Rauhala, 2013; Reuters, 2013).

<sup>11</sup>Andrews, S.Q. (2014). China's air pollution reporting is misleading. China Dialogue. Posted: 27 March 2014. Available at: <https://www.chinadialogue.net/article/show/single/en/6856-China-s-air-pollution-reporting-is-misleading>



Bhushal (2019) explains that a 2018 US report, 'Hazy Perceptions' analysed "more than half a million social media posts between 2015 to 2018 in India, Sri Lanka, Nepal, Philippines, Papua New Guinea, Indonesia, Thailand, Malaysia, Singapore, Mongolia and Pakistan" and concluded that social media and news coverage in South and Southeast Asia built "a hazy public perception of air pollution". In other words, people's perceptions about air pollution do not match the evidence on air pollution and its different sources.

Bhushal further explains (ibid.) that there is a gap between actual sources and commonly discussed sources of air pollution in people's perceptions. Although in these countries' household fuels, power plants and waste burning are the major sources of air pollution, in the media outlets vehicular emissions receive the most attention. As a result, the public has a false perception of what the real issues are that need to be addressed.

#### 1.4.3 If only we made the invisible visible...

Building this argument further, it is often suggested that there is a lack of civic and political action and grassroots social movements around imperceptible pollutants for the very reason that they are invisible (Invisible Dust, 2019; BreathLife, 2019; iScape, 2019; Making Sense, 2019). In their public messaging various organisations also suggest that "awareness is a prelude to informed action" (UNESCO, 1997; Invisible Dust, 2019). While these are crucial first steps, information and awareness alone are not enough to enable sustained civic and political action.



Figure 17. A screenshot of the tweet of Damien Hall on the 13th of April 2018 of Tim Rodaway's presentation<sup>12</sup>

The common perception is that the more visible pollution is, then the more likely people will be to do something about it. While in some cases this might be true, Gould (1993, p.157) argues that what often “appears to be the most obvious or intuitive might be false”. As he puts it (ibid., p.158):

“[in some cases] neither the social visibility of pollution, the severity of its impacts, the identification of its sources, nor the proximity of local populations to those sources has had a direct impact on the level or nature of local environmental political mobilization.”

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<sup>12</sup>Tweet of Damien Hall (2018): Available at: [https://twitter.com/hall\\_damien/status/984789938104356865](https://twitter.com/hall_damien/status/984789938104356865)



Looking at shocking examples of man-made environmental disasters—including the toxic waste contamination of the Love Canal (The Atlantic, 1979), the dioxin pollution of Times Beach (The St. Louis Post-Dispatch, 2017), and the poisoned soil of New Orleans and Silicon Valley (Situating Systems, 2016)—the visibility and tangibility of contaminants were not always enough to raise wider and sustained political action. Looking to the present, air pollution in Delhi is often so high (Reuters in Delhi, 2019; Reuters, 2018; Biswas, 2017; India Untamed, 2014) that it exceeds what current sensing technologies can even measure, yet decision makers have taken little action to improve the situation.

There are also many cases where environmental pollution was misrepresented with harmful effects, such as those described in Klinenberg’s social autopsy of the 1995 Chicago heat wave and Gill’s study (Gill et al., 2011) of Japan’s response to the Fukushima Daiichi nuclear disaster.



Figure 18. A screenshot from the documentary ‘Under the Dome’ (2015) by Chai Jing: “The most serious flight delay in Beijing capital airport due to fog...”, demonstrating how the Chinese media misrepresented pollution as “fog” and managed to change public perception for twenty years<sup>13</sup>

<sup>13</sup>The documentary ‘Under the Dome’ was directed by Chai Jing, a former China Central Television journalist, concerning air pollution in China. It was released on the 25th of February 2015. As Wikipedia states (2018) [the documentary] was “viewed over 150 million times on Tencent within three days of its release and had been viewed a further 150 million times (total 300 million views) by the time it was taken offline four days later”. Available at: [https://en.wikipedia.org/wiki/Under\\_the\\_Dome\\_\(film\)](https://en.wikipedia.org/wiki/Under_the_Dome_(film))

Kuchinskaya (2014, p.160) argues that “public visibility [of pollution] depends on whose voices can be heard and which groups have institutional and infrastructural support”. In her discussion of the Chernobyl nuclear disaster, she describes the politics and “production of invisibility”, its consequences for the people of Belarus and the “various strategies used by industries to displace dangerous toxins as objects of public attention” (ibid.).

Kuchinskaya (ibid.) goes on to describe how in these cases public debates on hazards have been reframed:

“promoting fake debate where there was a scientific consensus, silencing critics, orchestrating studies to counter even strong evidence of harm, blaming victims’ genetic makeup or lifestyles, and also presenting a lack of monitoring as an absence of health effects.”

Similarly to radiation, air pollution and climate change can also be made either more salient and publicly visible or unobservable, depending on how their effects are represented. It is therefore crucial to understand the current ways in which politically- and technologically-driven invisibility around air pollution is constructed and investigate how pollution could be made more socially visible.

Gabrys (2018, p.509) argues that in citizen sensing projects, for example, new insights might unfold in practice by testing the “very articulations of citizenship that technologies may facilitate” (p.508):

“The notion that a device might embody and enable particular forms of environmental citizenship can be tested, challenged, and re-routed. By taking up citizen sensing technologies in practice, and through repeated use and asking how they actually do – or do not – allow for environmental citizenship, participants might challenge the claims made about devices, while also developing and inventing alternative capacities for citizen sensing technologies. Citizen sensing research and practice might expand from their usual framing as sensing technologies toward political action to encompass a more inventive and open set of engagements.”

To avoid fake public debates and the displacement of environmental pollutants as objects of public attention (Kuchinskaya, 2014), “democratising the collection and use of environmental data through citizen sensing” alone (Gabrys, 2015) might not be enough. It seems as if somehow

the narratives that derive from and make sense of that data, and are told to the public, also have to be ‘democratised’.

This line of thinking then raises the question: could design research be applied to improve the legitimacy of public decision making and give citizens greater degrees of participation in understanding and reducing pollution in cities?

## 1.5 The current technological narratives of air pollution

The degree of participation that current sensing technologies afford are still limited to:

### 1.5.1 Avoid it, don’t face it!

Currently citizens are presented with a narrative that gives them little agency to tackle air pollution. In this thesis I use the term agency in a similar way to Jeremijenko (2012), posing the question: how does any one of us address the complex and important environmental and societal challenges we face in the 21st century? In regard to air pollution, citizens can either change their behaviour to reduce (mitigate) their personal impact on pollution or minimise their exposure to its harmful effects by downloading apps and visualisations. Encouraging people to find a cleaner route – and simply avoid pollution – though might be problematic in the long-term as it gives the false impression that pollution is something over which they have no control over, when they can actually do improve pollution through a range of different actions.



Figure 19. A screenshot from an article on Plume Labs and their work<sup>14</sup>

In addition to this, while finding a cleaner route to work or school can be beneficial for health (City of London, 2018; CityAir App, 2018), according to interviews that have been conducted during my work prior to this PhD, app users tend to prioritise time and practicality over their health. When in a rush or to save time, people often take the shortest route regardless of the associated health risks.

### 1.5.2 Just observe passively – Data Spectatorship

Hundreds of sensing applications that are currently available on the market visualise air pollution through emojis, numbers, colours and graphs. The same way as in my own work prior to this PhD with communities affected by pollution, after a while only observing pollution through these apps often increases anxiety and people easily get disheartened how air quality could be actually improved.

<sup>14</sup>O'Brien, C. (2015). With air pollution app, Plume Labs wants to prove that big data and open government can save lives. Posted: 1 October 2015. Available at: <https://venturebeat.com/2015/10/01/with-air-pollution-app-plume-labs-wants-to-prove-that-big-data-and-open-government-can-save-lives/>

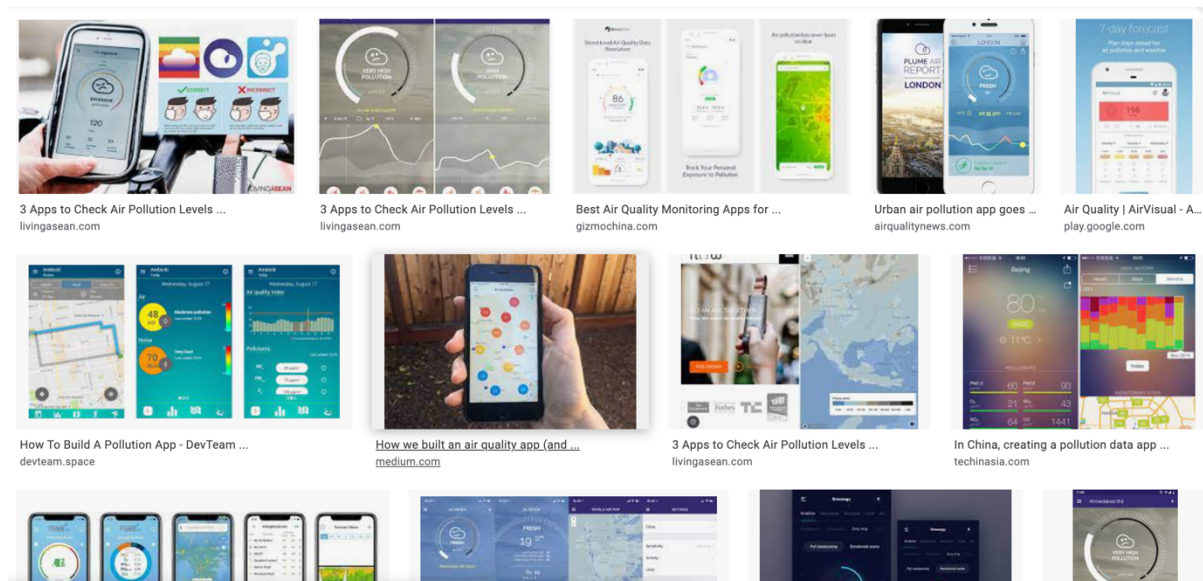


Figure 20. A Google snapshot of different air pollution monitoring apps visualising air pollution through emojis, numbers, colours and graphs

When people do gather data with their sensor and they get a number, they might think: Wow, I got a graph..., and that seems to be the “aha” moment. Haque (in a personal interview in 2015) further argues that:

“the challenge with this kind of data spectatorship is that we look at numbers instead of the thing itself that is collecting on our screen. In order to step beyond the kind of data spectatorship aspect of monitoring pollution, the aim could be to see something in the data and even re-imagine the measuring process itself. Instead of looking at a number and that for instance, the current CO<sub>2</sub> level on a device is 339.65 ppm, questions should focus on the complexity of the decisions that people make, that process why people would start using their cars less this week than last week, because they do want to breathe better air”.

In the field of design for behaviour change, similarly to Haque’s argument, Lockton (2015) questions “what agency is possible”, and “how to enact change”. He encourages practitioners to design tools that connect people’s understanding of how things work and how they can act, around everything from cities, the environment, networked infrastructure to social, civic and political contexts (ibid.). He offers a five-level action programme, “designing agency” and describes Level 5 as something that would “challenge common behavioural design paradigms” and “direct ways of enabling action, empowering people to change the behaviour of the systems in which they live” (ibid.).

Reflecting on both the arguments and questions of Haque and Lockton, a gap in knowledge has started to emerge. In order to step beyond the kind of pollution-data spectatorship that current sensing technologies offer, could design research be applied to re-imagine the measuring process itself? Furthermore, could design research be applied to design a practical tool that not only supports “people to understand the wider contexts of their actions and their agency within society” (Lockton, 2015) but gives them “direct ways of enabling action” (ibid.) and enables them “to change the behaviour of the systems in which they live” (ibid.) to reduce pollution in cities?

### 1.5.3 Focus on mitigation, instead of preventative actions

Technological and top-down solutions are often focussed on measuring and mitigating the effects of pollution that has already been emitted, rather than preventing it from being produced in the first place. Many local and national governments often put energy and investment into fig leaf interventions, which are politically popular but have only marginal impacts on the sources of pollution (Khan, 2018; Kentish, 2017). For example, the UK Government recently suggested that councils remove speed bumps from their roads to improve air quality (See Figure 1.11). Though this would likely have a positive effect on local air quality – recent evidence indicates that “a diesel car emits 98 per cent more nitrogen dioxide when driving over speed bumps” due to breaking and hard acceleration – the main source of the pollution, traffic, will stay the same. By focussing on these aspects of the problem, some suggest that the Government is avoiding taking more difficult and politically unpopular actions: “ministers say they want councils to use [these] methods, such as changing road layouts, before introducing new charges on drivers” (Kentish, 2017).

# Speed bumps could disappear from UK roads as part of Government plan to tackle air pollution

Government tells councils to 'optimise traffic flow' and scrap humps

Benjamin Kentish | @BenKentish | Thursday 27 July 2017 12:17 BST | 100 comments



Like Click to follow The Independent Online



Figure 21. A screenshot from an article on Independent: “Michael Gove wants councils to introduce levies on diesel vehicles only as a last resort” (Kentish, 2017)<sup>15</sup>

Dealing with pollution after it's been produced, rather than preventing it in the first place, is an age-old approach. For example, a blueprint from 1913 was recently uncovered in the London Metropolitan Archives describing an “air cannon” that would “blast away” the city's air pollution.

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<sup>15</sup>Kentish, B. (2017). Speed bumps could disappear from UK roads as part of Government plan to tackle air pollution. Independent. Posted: 27 July 2017. Available at: <https://www.independent.co.uk/news/uk/home-news/speed-bumps-disappear-uk-roads-air-pollution-government-plan-emissions-councils-remove-a7862811.html>



## BLUE SKY THINKING INVENTOR'S BID TO BLAST AWAY POLLUTION A CENTURY AGO REVEALED



LONDON METROPOLITAN ARCHIVES/CITY OF LONDON CORPORATION

AN “air cannon” to blast away London’s filthy air has been revealed as one of the more fanciful ideas for beating the city’s centuries-old pollution crisis.

The blueprint from 1913 uncovered at the London Metropolitan Archives claimed the 60ft-long, gas-powered “Fog Battery” would blast through the capital’s “densest fog” at 300mph.

A corkscrew of vibrations would push toxic air to an altitude where “the wind will carry it away”, the diagram’s

annotations claim. Each explosion at the cannon’s base would be sparked by acetylene and cost about £2.30 in today’s money.

Pollution at the time was worse than today because of coal burned for heating and power.

The idea was part of submissions for “London of 1925”, but did not make it off the drawing board. Its designer, an Italian professor, foresaw dotting 12 batteries on hills around London.

**Mark Blunden**

Figure 22. A screenshot of London Air’s tweet of the Evening Standard’s introducing an air cannon that would “blast away” pollution in the city of London.<sup>16</sup>

This line of thinking is also prominent in the private sector. Some schools in China, for instance, have built domes with air-filtration systems (see Figure 1.12) so children can play safely outdoors despite the dangerous levels of air pollution found in most urban areas.

<sup>16</sup>Tweet of London Air (2019): <https://twitter.com/LondonAir/status/1093928014415646722>



living in Beijing, I think many mothers are fed up with keeping their children inside.”



Students at the International School of Beijing playing in one of two domes with air-filtration systems for when smog is severe. Adam Dean for The New York Times

Figure 23. A screenshot from an article in the New York Times (Wong, April 22, 2013): “Students at the International School of Beijing playing in one of two domes with air-filtration systems for when smog is severe”.<sup>17</sup>

<sup>17</sup>Wong, E. (2013). In China, Breathing Becomes a Childhood Risk. Posted: 22 April 2013. Available at: <https://www.nytimes.com/2013/04/23/world/asia/pollution-is-radically-changing-childhood-in-chinas-cities.html>



**Indy Johar**  
@indy\_johar

Follow



## Solving the wrong problem ... @SadiqKhan

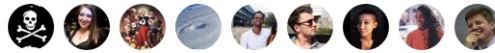


**Sadiq Khan** @SadiqKhan

London's toxic air is harming our children's health. This can't go on. Today we've announced our latest plans - new indoor air pollution filtration systems in nurseries to help us tackle the polluted air from our congested roads. ...

11:30 AM - 3 Dec 2018

8 Retweets 34 Likes



1   8   34  

Figure 24. A screenshot of Indy Johar's tweet commenting on Sadiq Khan's tweet on deploying new indoor air filtration systems in nurseries.<sup>18</sup>

There are also a number of products on the market designed to filter the air around people, including anti-pollution bus stops (Balogh, 2017) and large-scale air purifiers (Garfield & Thomson, 2018).

<sup>18</sup>Tweet of Indy Johar (2018). Available at: [https://twitter.com/indy\\_johar/status/1069675280753721344](https://twitter.com/indy_johar/status/1069675280753721344)

# The world's first 'smog vacuum cleaner' can suck up air pollution and turn it into jewellery

In 2015, a Dutch designer invented an air purifier to help fight air pollution. First, it came to Rotterdam and four Chinese cities. Now, it's going to Poland



Figure 25. A screenshot from an article of Independent: "In 2015, a Dutch designer invented an air purifier to help fight air pollution. First, it came to Rotterdam and four Chinese cities. Now, it's going to Poland."<sup>19</sup>

The distinction between mitigation and prevention, specifically in the case of air quality, is necessary. As Johnson explains (2015) both terms are used to express the reduction of risk. While both are very important, "prevention aims to stop an event from happening in the first place, whereas mitigation tries to limit the damage" (ibid.). Making this distinction is crucial when designing tools to improve air quality.

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<sup>19</sup>Thomson, C. The world's first 'smog vacuum cleaner' can suck up air pollution and turn it into jewellery. Independent. Independent. Posted: 29 January 2018. Available at: <https://www.independent.co.uk/environment/smog-vacuum-cleaner-air-pollution-daan-roosegaarde-netherlands-china-poland-a8183236.html>

As Semenza et al. describes (2011, p.10), in the case of climate change – as this might be a useful distinction, mitigation refers to:

“reductions in greenhouse gas emissions and augmentation in greenhouse gas sinks intended to minimize the extent of global warming. These steps include energy conservation by increasing the fuel efficiency of vehicles; switching to cleaner energy sources by changing business practices; or carbon sequestration through tropical reforestation. While adaptation entails adjustments of environmental or social settings in response to past, current or anticipated climatic events and their impacts in order to moderate their consequences.”

Rather than simply monitoring, visualising or observing pollution that has already been produced (mitigation), how could we design tools for citizen engagement and behaviour change to prevent pollution from being produced in the first place (prevention)?

## 1.6 The degree of participation

The degree of participation afforded by these narratives and air quality sensing applications can be assessed using Sherry Arnstein’s (1969, pp. 217) “Ladder of Citizen Participation” – describing the progressive degrees of “citizen involvement in planning processes in the United States” (The Citizen’s Handbook, 2019).

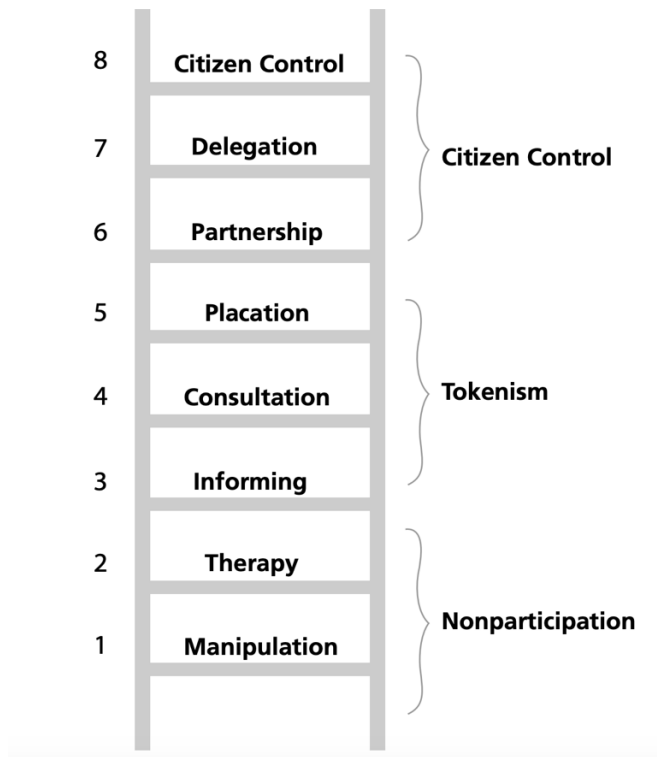


Figure 26. A screenshot from the website of the Citizen's Handbook on Arnstein's Ladder of Citizen Participation (1969, p.217)<sup>20</sup>

As Dobson (2018) explains, “the ladder is a guide to seeing who has power when important decisions are being made”.

<sup>20</sup>The Citizen's Handbook (2019): Available at: <https://www.citizenshandbook.org/arnsteinsladder.html>

**1 Manipulation and 2 Therapy.** Both are non participative. The aim is to cure or educate the participants. The proposed plan is best and the job of participation is to achieve public support through public relations.

**3 Informing.** A most important first step to legitimate participation. But too frequently the emphasis is on a one way flow of information. No channel for feedback.

**4 Consultation.** Again a legitimate step attitude surveys, neighbourhood meetings and public enquiries. But Arnstein still feels this is just a window dressing ritual.

**5 Placation.** For example, co-option of hand-picked 'worthies' onto committees. It allows citizens to advise or plan ad infinitum but retains for power holders the right to judge the legitimacy or feasibility of the advice.

**6 Partnership.** Power is in fact redistributed through negotiation between citizens and power holders. Planning and decision-making responsibilities are shared e.g. through joint committees.

**7 Delegation.** Citizens holding a clear majority of seats on committees with delegated powers to make decisions. Public now has the power to assure accountability of the programme to them.

**8 Citizen Control.** Have-nots handle the entire job of planning, policy making and managing a programme e.g. neighbourhood corporation with no intermediaries between it and the source of funds.

*Figure 27. David Wilcox describes the 8 rungs of the ladder.<sup>21</sup> Photo © Screenshot of the website of The Citizen's Handbook*

Expanding on the same questions as Mazé (2013, p.106) Arnstein also discusses the popular rhetoric of citizen participation in decision making processes. Both Arnstein (1969) and Mazé (2013) question whether this shift actually represents the redistribution of rights or if it is more about the devolution of state responsibilities as a means of coping with a lack of public resources. They also note that it is difficult for those in power to find a balance of how much they can empower communities to become more resilient without giving them so much power that they would overrule their own authority (ibid.; ibid.).

As Shipley and Utz (2012, p.9) explain Arnstein's model not only emphasised the shift "from token or manipulated participation to partnership or even delegation of power" but also

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<sup>21</sup>Wilcox, D. (1998). Sherry Arnstein. Available at: <http://www.partnerships.org.uk/part/arn.htm>

promoted the “redistribution of decision making to underprivileged citizens”.

Although further discussion on this topic is beyond the scope of this thesis, Guaraldo (1996) critiques Arnstein’s ladder and says that it only works for participation in developed countries and it’s insufficient for developing ones because the state isn’t as strong and/or involved (Shipley & Utz, 2012, p.9). To improve on the model, Guaraldo suggests the following seven additional rungs: Self-management, Conspiracy, Diplomacy, Dissimulation, Conciliation, Partnership, Empowerment (p.10).

### 1.7 Moving up the ladder through design

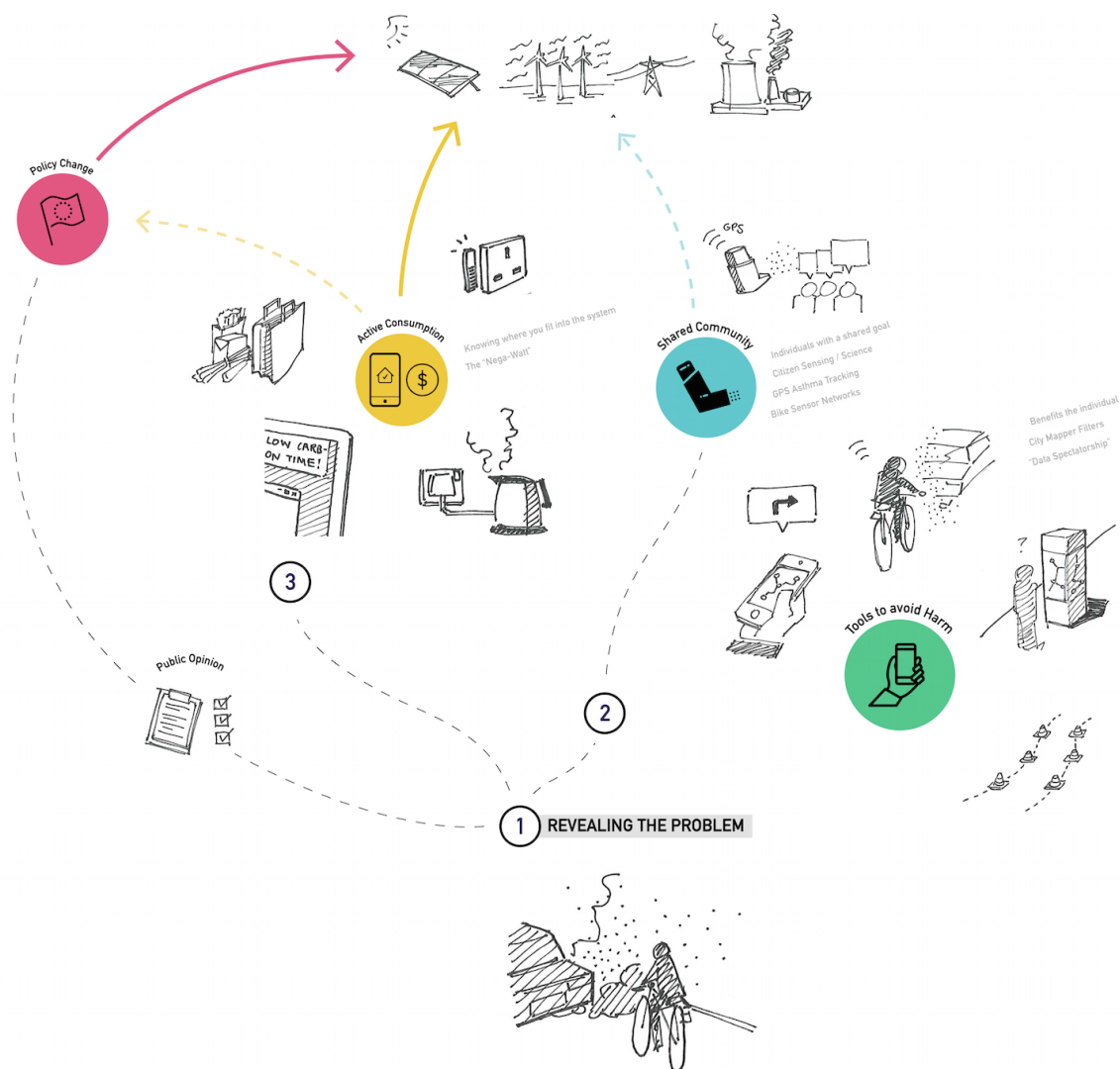


Figure 28. A sketch describing current approaches to and new opportunities for addressing air pollution sensing. Illustration © Geoffrey Stevens, Niklas Hagemann & Gyorgyi Galik

Supporting questions about participation through smart technologies, the argument that has started forming so far is (see Figure 27.):

1) Today's air pollution-related smart city projects simply reveal the problem of air pollution while 'Cleaner-route' apps – based on the data from sensors – help people to react and find a cleaner route to school, work and home (CleanAir, 2019, City Air app, 2020).

2) Other technologies take a more systemic and “active” approach to the problem. They not only generate and share air quality data, but also take steps to protect vulnerable communities that would otherwise be affected by pollution. An inspiring example of this is Propeller Health (aka Asthmapolis), which connects patients asthma inhalers to their smartphones and a network of other users, the platform helps to prevent unnecessary asthma attacks (Propeller Health, 2019). Whenever a user walks into a polluted area (or an area where someone else has recently used their inhaler) the system sends out a notification alerting them of the risk.

3) Though there have been successful trials – for example, in the transport sector, with temporary bans and car free days (Garfield, 2018; O'Sullivan, 2018) – it could still take years or even decades to bring about the policy changes needed to improve urban air pollution on a wide scale.

To summarise the key points that have been raised so far in this PhD and settle on the final research questions:

Reducing pollution in cities is crucial to the protection of human health, which will also benefit climate change mitigation. And doing this will require an understanding of how pollution is made invisible or more socially visible through current political and technological narratives.

Moving beyond mitigative actions (which won't be enough to address the complexity and severity of this challenge alone) this enquiry is focused on using design research practices to developing a set of design experiments that could shift the focus from pollution monitoring (measuring pollution that has already been produced) to pollution prevention (pre-empting pollution before it is produced).

To enable the prevention of pollution, it aims to achieve two outcomes: to pre-empt polluting



and energy-intensive behaviours before they even happen, and to aggregate the impact of those preventative behaviours by enabling collective action with a group of engaged individuals.

As such, this thesis raises the following research questions:

(1) Could a connected technology be designed to engender preventative behaviours and afford a more proactive role for citizens in making and/or supporting the decisions that prevent pollution in cities? (bottom-up, individual change)

2) If networked<sup>22</sup>, could a novel interaction be designed to stimulate societal demand for environmental regulation (top-down, systems change) and to aggregate the small impact of individuals to achieve a greater collective impact?

Rather than designing and investing into the development of a new system or device, could it be possible to piggyback onto an existing system that already has a large community of users?

AI assistants are expected to become a bigger part of our daily lives. The number of people using digital assistants is “projected to increase to 1.8 billion by 2021” (Richter, 2016). The technology is already present across a wide variety of industry sectors, including retail, healthcare, education and the automotive industry (Global Market Insights, 2017). In 2017, Amazon’s Alexa devices, for example, were already in over seven million households (TechCrunch, 2017); today Amazon estimates it has sold more than 100 million devices (TechCrunch, 2019).

Given the growing abilities and reach of AI assistants, it offers a potentially exciting opportunity to consider their current and potential future uses. While keeping in mind that AI home assistants still have considerable technological limitations, is there an opportunity for: (1) AI technology providers to go beyond current services of convenience and entertainment and provide more socially-sensitive purposes in the future; and (2) designers to explore how these applications – and technologies beyond AI assistants – could be designed to enable behaviour change and engender a more proactive role for citizens in preventing pollution in cities.

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<sup>22</sup>In this thesis, as Computer Hope describes (2018) the word ‘network’ refers to “a collection of computers or devices [that are] connected to one another to allow the sharing of data”.

## 1.8 Situating the thesis – Action research & participatory design

In participatory design, “stakeholders – especially users, developers and planners – cooperatively make or adjust systems, technologies and artefacts in ways which fit more appropriately to the needs of those who are going to use them” (Bannon & Ehn, 2012, p.41).

One of the first designers to adopt participatory design principles was Kristen Nygaard. Working with the Norwegian Iron and Metal Workers Union in 1972, he “took a first move from traditional research and development of computer systems into working with people – directly changing and making more active the role of the local unions” (Sundblad, 2010, p.2).

As Bødker (2003, p.87) argues, that “research-based participatory design is needed when designing new technologies” to question their use and offer alternatives (ibid., p.89):

“[participatory designers] commit to working with people, groups or organisations to explore what current and future technologies may support them in their particular setting. Not so much to build their future technology but to help them realize that they have a choice.”

Participatory design “attempts to change situations, not simply study them” (Bannon & Ehn, 2012, p.42). The field has its origins after the Second World War at the Tavistock Institute in London, where researchers were studying ‘socio-technical systems’ and in particular those related to coal mining in the UK (ibid., p.42). Initially focusing on the civil repatriation of German prisoners of war, Trist who was a crucial figure contributing to the methodological framework of action research – looking at large-scale, multi-organizational problems – was also working at the Tavistock Institute of Human Relations as a social psychiatrist (O’Brien, 1998).

Systems engineering solutions that had been recently introduced to UK workplaces were not achieving the productivity gains that had been expected (ibid). Developing the technical subsystem without considering the design of the social subsystem – had resulted in “project failures and poor performance” (ibid). With this in mind, researchers began developing an approach to “join and optimise” (ibid.) two or more systems together. Instead of focusing on technology design itself, they tried to understand “how technology was introduced and used” (ibid).

Building on the Tavistock Institute's research, a new approach to systems design known as the 'Scandinavian approach' emerged as a political critique of the socio-technical perspective (ibid., p.43). As Bannon & Ehn (ibid.) put it:

“Supporting workers in understanding the way computers and applications worked was a starting point, but the objective was to attempt to change how these systems worked, to allow for greater human flexibility in the use of systems. The realisation that what was needed was a clear move into the design of technology itself.”

The Scandinavian approach to systems design partly inspired this practice-led PhD thesis, in which, with a group of participants, two experiments will be developed. In the first experiment a new skill for an existing voice-user interface will be designed, developed and tested with a group of participants. And in the second experiment, with another group of participants, a new design method and voice user interface will be designed and tested in participants' homes.

Both the Scandinavian approach to systems design and the socio-technical tradition, for the type of research and design interventions they developed, took inspiration and insights from action-research (Bannon & Ehn, 2012, p.44). By developing my experiments detailed in chapters 3 and 4, I will engage in action research.

Following Fisher's argument (2004, p.3) on the type of situations that action research can be best applied, action research seems the best suited methodology to the experiments: “the challenge [in this case, air pollution] being investigated is very complex (involving diverse elements)”; the researcher and participants are not yet sure where to start in addressing this challenge; “the change might involve people with differing perspectives or conflicting objectives; and there is a need for a common vision or negotiated compromise;”

As O'Brien (1998) explains that in action research “the research takes place in real-world situations and aims to solve real problems; the initiating researcher makes no attempt to remain objective and openly acknowledges their bias to the other participants.” For many designers and researchers aiming to effect change in society, this methodological framework introduced new ways of thinking and learning by doing things (Fisher & Jackson, 1998, p.8).

Kurt Lewin (1944) describes action research as “a comparative research on the conditions and effects of various forms of social action and research leading to social action” (Lewin 1946, p.35), involving a spiral of steps, in which each step is made up of a circle of 1) planning, 2) action and 3) fact-finding about the impact of the action (Lewin 1946, p.38). Kemmis et al. (2014) has a different model with an iterative, cyclical nature of four steps: plan, act, observe, reflect, while Susman (O’Brien, 1998) is applying the five steps of diagnosing, action planning, taking action, evaluating and specifying learning in action research. In contrast to most type of research where the research is confined by “specific research questions”, by focusing on a “general problem area that the researchers and participants” aim to improve, the “research questions [in action research] may change for different cycles” (Fisher, 2006, p.3).

Gilmore et al. (1986, p.161) describes action research as:

"Action research...aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process."

Fisher (2004, p.2) notes that some advocates of action research believe that action research must be participatory, while “others use the term Participatory Action Research (PAR) to refer to more explicitly participatory forms of action research”. Fisher goes on to differentiate “between action research where a group of researchers go through the action research cycle and PAR where other actors (such as community members) are actively involved in managing the research process” (ibid.). Fisher and Jackson (1998, p.3) explains that action research also contributes to public knowledge, it is not only for the enhancement of individual knowledge:

“Experience in a specific situation generates insights and understanding which can inform actions in similar situations. The word inform is important here. The intention is not to provide recipes for implementation, but rather to provide insights which others may find useful in other contexts. This aspect of generalising from learning in a specific situation is the research element.”

### 1.8.1 The ideals underpinning our designed visions of the future

In 2016, Mazé (2016b, p.1) examined the rise of futures studies in Europe. She found that there was increased public appetite for participating in the formation of long-term national policies due to growing awareness of issues such as climate change (ibid.), and that design is becoming an increasingly powerful discipline. As a warning to designers who are engaged with social and political issues, she suggests that when mobilising particular ideas or ideals of the future, it is important “to make explicit and reflect upon the assumptions, norms and ideals underlying designed visions of the future” (p.2). This includes the role that designers may have in “(re)producing or countering social norms, practices and structures” (ibid.). As design visions will have “tangible consequences on the understandings, aspirations and behaviours of public society” (ibid.) – she believes that this warning will be ever more relevant.

As this thesis will involve a series of design experiments in the home setting with AI assistants (please see in Chapters 3 & 4), Mazé’s questions are especially relevant. It seems inevitable that my own biases and assumptions about ‘smartness’, sustainability and behaviour change will find their way into the prototypes. With Mazé’s critique about design and the designer in mind, this thesis will aim to make these assumptions explicit whenever possible.

Air pollution-related smart city projects often allude to behaviour change by talking about ‘persuasion’, ‘nudging’ and the design of new technologies to ‘enable behaviour change’ (Smets & Lievens, 2018; Bousquet, 2017a; Glowacki, 2016;). The following chapter is divided into three sections: 1) a review of specific models of behaviour and theories for change (Section 2.6.2); 2) discussion of those models that could be applied to technology design (Sections 2.2); and 3) discussion of those technologies that could be applied to reduce pollution in cities.

For the duration of this PhD, I operate with the goal that energy behaviours need to be shifted or changed in order to reduce pollution in cities. I apply design research to better understand the means by which this can be best achieved.

## Chapter 2. Design for behaviour change

Transitioning towards a low-pollution society will require not only new technologies, but also new practices of energy use. As the different behaviours of individuals producing air pollution often overlap with those behaviours that need to be changed to mitigate climate change, this chapter looks at both challenges together and as to how air pollution could be improved by applying behavioural insights aiming at improving climate change. After exploring these insights, we now look at how behavioural insights have been applied in the field of design for behaviour change and also introduces where the idea for the experiments of this practice-led PhD came from.

Lockton et al. (2014c) explains that reducing our energy use through influencing people's behaviour – and as a result reducing our carbon dioxide emissions – is a “significant research topic across multiple intersecting technological and social science disciplines” (p.1).

As Lockton et al. explain (2014c, p.1) energy use is one of the key challenges on which design for behaviour change – particularly, design for sustainable behaviour – has focused. As he puts it:

“[design for behaviour change] aims to reduce the undesirable social and environmental impacts of products and services, or increase the desired impacts, through design (in a broad sense) concentrating on understanding and influencing people's interactions with technology. It is inherently multidisciplinary, drawing on knowledge, perspectives and models from a number of fields relating to human behaviour.”

A range of Lockton's work (Lockton, 2012; Lockton et al., 2014c; Lockton, 2017; Niedderer et al., 2014) describes how design for behaviour change applies some of the insights of the field of human-computer interaction (HCI) on persuasive technology and of behavioural economics.

Lockton (2014b) also notes that:

“many kinds of ‘intervention’ are simply not nuanced enough to address the complexity and diversity of real people, making situated decisions in real-life contexts, embedded in the complex webs of social practices that everyday life entails.”

He goes on to argue that this issue is also present in many current “behavioural economics-inspired treatments of complex social issues” (ibid.).

Brynjarsdóttir *et al.* (2012) also reviewed a large body of research on persuasive technologies that are designed to improve human and environmental health through behaviour change. The authors (ibid., p.947) explain that environmental sustainability – addressed through persuasion – is a popular topic in HCI research. They go on to describe (ibid., p.949) that although “the [reviewed] papers allude to behaviour change as their general goal”, many seem to focus more on “increasing awareness” – suggesting that increasing people’s awareness of energy consumption will lead to reduction of their energy use. Many of the projects described have no user evaluation, they work with a small group of participants with no or limited evidence of lasting behavioural impact (ibid., p.949). These tools often focus on behaviours at the individual scale and without considering “the cognitive limitations and the role of emotion in decision-making” and that habits play in many people’s everyday behaviours (ibid., p.952). Many of the projects the authors analyse discount the importance of aspects of daily life – the institutional, structural and infrastructural barriers (Ockwell *et al.*, 2009, pp. 308-309) – “that an individual cannot alter” (Brynjarsdóttir *et al.*, p.949). They ignore questions as to “who is actually able to make changes, or how this will change political relationships or social norms” (ibid., p.952). They do not “consider energy in the context of broader socio-cultural practices” (ibid., p.954).

Brynjarsdóttir *et al.* (2012) also points out that HCI and persuasive technologies often frame human behaviour with respect to metrics that can be quantified, and by doing that, “these technologies limit their focus to aspects of sustainability that are clearly measurable” (ibid., p.951). This results in leaving out many of the behaviours that could also support sustainability.

Supporting this argument, during a workshop – prior to this PhD – that was exploring the potential of food waste collection, as a means for a London borough to reduce the cost of waste disposal services (WRAP, 2018), a council member presented the following slide on the waste hierarchy:

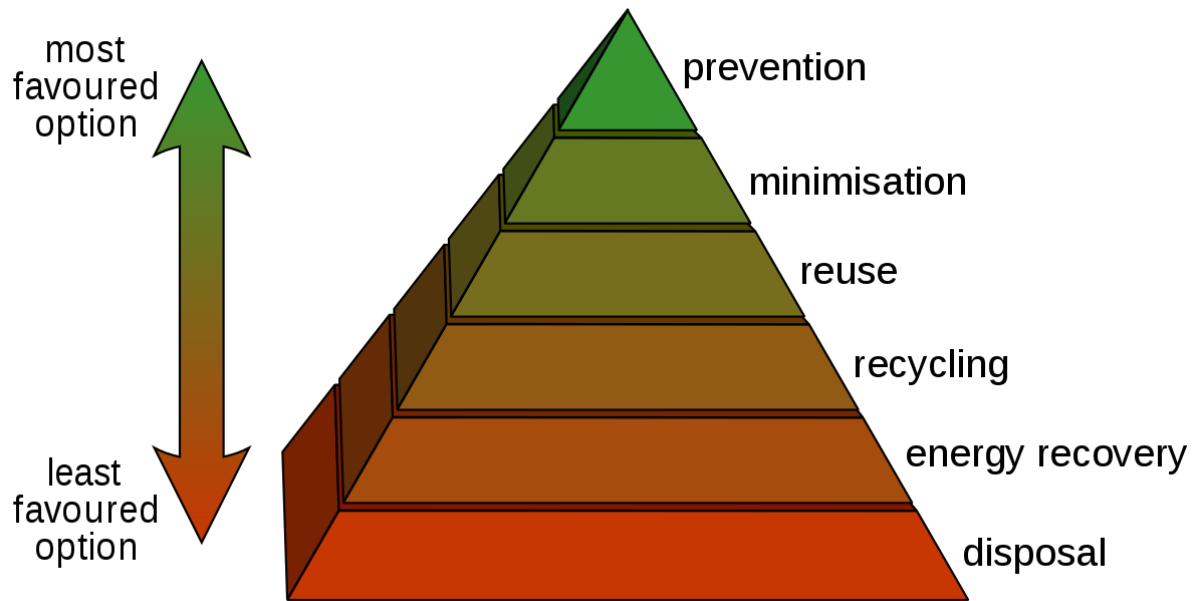


Figure 29. A diagram of the waste hierarchy on Wikipedia (2019): “waste hierarchy is a tool used in the evaluation of processes that protect the environment – alongside resource and energy consumption – to most favourable to least favourable actions.” Photo © Drstuey, CC BY-SA 3.0, Wikipedia<sup>23</sup>

She presented this slide with the intention of showing that most sustainability narratives focus too much on recycling and not enough on prevention. In the waste hierarchy, recycling is only the fourth most important action one can take to become more sustainable. The most important action is prevention – or not wasting food in the first place.

According to the research insights of Project Drawdown (2018), the third most important action to mitigate climate change is reducing food waste. The actions on their list are selected not only for their impact on climate change, but also for their intrinsic benefits to communities and economies:

“With a third of the food raised not making it from farm or factory to fork, food waste is responsible for roughly 8% of global emissions. In low income regions, wastage is generally unintentional and occurs earlier in the supply chain—food rots on farms or during storage and distribution. In higher-income regions, wastage is typically willful and occurs further along the supply chain. Retailers and consumers often reject food based on bumps, bruises, and coloring, or simply order, buy, or serve too much. Up to 35% of food in higher-income economies is thrown out by consumers. In lower-income countries, it is essential to improve

<sup>23</sup>Waste hierarchy (2019). Available at: [https://en.wikipedia.org/wiki/Waste\\_hierarchy](https://en.wikipedia.org/wiki/Waste_hierarchy)



infrastructure for storage, processing, and transportation. In higher-income regions, however, widespread change is needed at the retail and consumer levels.”

Given all of the compelling reasons to prevent waste, why do local governments tend to focus their efforts on recycling? As the council member explained, political performance is measured through key performance indicators (KPIs) – quantifiable measures used to evaluate the success of an organisation, employee, etc. in meeting a set of predetermined objectives. The reason that public sustainability campaigns tend to focus their efforts on recycling is that prevention is difficult to measure. As she said, “convincing someone not to buy and waste something in the first place is not measurable” while it is possible to say, “we increase recycling rates by 40%”.

Brynjarsdóttir et al. (ibid.) also describe that the emphasis on “providing information as a driver for behaviour change rests on a common modernist assumption that people are rational actors seeking to optimise their activities based on what they know” (ibid., p.952). The authors argue that “ambient displays using pervasive sensor technology, ambient computer widgets, social network applications for sharing environmental data, persuasive games and interactive visual displays” (ibid., p. 948) are all designed to persuade people to reduce their energy consumption.

As Lockton et al. explain (2014c, p.1) in domestic environments, aside from bigger-scale infrastructural changes – such as retrofitting buildings through e.g. insulation of the attic, heat retention and reduced air leakage, efficient heating and ventilation systems (Retrofit for the Future, 2014), “the majority of work on influencing energy use through behaviour change concentrates on numerical, visual feedback displays for electricity or gas use” (Lockton et al., 2014c, p.2).

At home, energy and water use can be tracked by smart meters and visualised through digital displays and applications, which intend to educate and incentivise people to change their energy behaviours.

Lockton et al. (2014c, p.2) note that the “opportunities afforded by networked smart meters [for example] enabling adaptive pricing changes” are being tested. In the UK specifically, these initiatives are being encouraged by current legislation, where policy for “all homes and small businesses support to have smart meters installed, with displays, by 2020” (ibid.). They go on to emphasise that while some changes in behaviour as a result of feedback displays indeed led to

some reduction in energy use, “simple numerical feedback may not take account of the realities of household life” (ibid.).

Hargreaves et al. (2018, p.127) go even further and question the evidence that smart home technologies actually achieve great energy savings and they note that “there is [even] a risk that they may generate forms of energy intensification”. They also point out that some firms, like Siemens, still claim that “smart home technologies can save up to 30% of energy costs without compromising comfort” (ibid.), and the smart home market is forecast to increase substantially. They argue that greater attention should be given to identify what these technologies should or could be used for (ibid., p.128).

As they (ibid., p.136) put it:

“It is vital that the energy saving claims are properly scrutinized to ensure SHTs are not being developed and sold on the basis of unrealistic and potentially misleading claims. Policy-makers have a potential role to play to generate standards, benchmarks and guidelines that ensure [that these technologies] are developed, tested and evaluated in ways that minimize the potential for energy intensification.”

Strengers (2013, p.25) explains that a core quality of the seamless integration of technology in the home is the achievement of “modernity” and “efficiency”. He notes that this idea of the “homes of tomorrow” (ibid.) can be found in the early 1930s’ future visions, in which efficiency was presented alongside “unprecedented levels of luxury, relaxation and indulgence, with excessive energy consumption clearly on display” (ibid.).

Building on Hargreaves *et al.* and Strengers’ insights, Darby (2018, p.141) also points at the “infantilizing and deactivating element of the smart home vision [that] can certainly be traced in the literature, implicitly if not explicitly, in the planned shift from human to machine sensing and control, and the development of ‘ambient intelligence’ that is capable of learning”.

Furthermore, Darby (ibid.) quotes Robins and Hepworth with their critique on visions of the smart home:

“computer home scenarios have a narrow and instrumental fixation on technique – the

‘evolution’ of the household is seen as an expression of some autonomous technological ‘progress’. The dream is a domestic machine-utopia...in which human agents are passive and infantilized. In such technocratic scripts the household is severed from its surrounding (economic, social and political) contexts.”

With all this in mind, what are some of the key elements or foundations that could support and lead to more successful outcomes with any given technological intervention that aims to enable behaviour change?

## 2.1 Improving government engagement and political will

As part of the Cambridge Climate Lecture Series, Kevin Anderson (2017) lists a set of opportunities for near-term mitigation and retooling our society towards a low-pollution future, which will need to be delivered in the next three decades if we are to avoid 4°C global temperature rise. These interventions would also impact local air pollution and include (ibid):

1. A shift to low or zero carbon energy supply;
2. Rapid penetration of more efficient end-use technologies;
3. A profound shift in our behaviour & practices;
4. The development of economic models that fit for purpose;
5. A massive program of electrification for heating / cooling, transport, industrial heating, etc.;
6. More stringent efficiency standards; and
7. The adoption of demand-side response<sup>24</sup>.

Marteau et al. (2011) and Ockwell et al. (2009) emphasise that enabling low carbon and low pollution behaviours will require direct government intervention.

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<sup>24</sup>As National Grid UK (2018) explains “demand side response refers to services that enable businesses and consumers to turn up, turn down or shift demand in real-time. DSR is an important tool to help ensure a secure, sustainable and affordable electricity system. It can help the national energy grid soften peaks in demand and fill in the troughs, especially at times when power is more abundant, affordable and clean. For businesses and consumers, DSR is a good way to save on total energy costs and reduce their carbon footprint. By encouraging greater participation through new ways of tackling the difference between energy supply and demand, an industrial problem could be turned into a consumer opportunity.”



Before photos by NYC DOT, After photos by Michael Grimm.

Figure 30. A screenshot from the article on “Times Square’s transformation into a pedestrian-friendly space”<sup>25</sup>

Ockwell et al. also (2009, p.312) explains that “despite regulation being a seemingly useful way of overcoming barriers to low carbon [and low pollution] behaviour”, governments are generally reserved when it comes to regulatory action for “fear of a negative public backlash” (p.313). The authors go on to emphasise that “across the political spectrum in both UK and US governments”, as well as in Australia, Germany, The Netherlands, and Singapore (Benartzi et al., 2017), instead of implementing stringent regulatory action, there is a “great interest in the latest methods to nudge lifestyles to a desired direction through informational approaches” (ibid.) and to promote individual, voluntary action (p.305).

While there are many positive examples of participatory approaches that have been effective in engaging people in reducing their emissions, including the grassroots initiatives of Global Action Plan, Carbon Reduction Action Groups, the UK Transition Town movement, carpooling, and

<sup>25</sup>Warekar, T. (2017). Times Square’s transformation into a pedestrian-friendly space captured in photos. Curbed NY. Posted: 19 April 2017. Available at: <https://ny.curbed.com/2017/4/19/15358234/times-square-snohetta-before-after-photos>

plastic bag bans (Ockwell et al., 2009, pp.316-317), most of these examples are “still relatively limited in scale” and it would be challenging to estimate how long it would take to implement them across society (ibid., p.317). The most successful efforts to change people’s attitudes and behaviours at a population scale (ibid., p.314) included the campaign against cigarette smoking and drunk driving, or the legislation aimed at increasing the use of seatbelts in cars. But as Michie et al. (2014) argue – despite strong evidence suggesting that smoking was linked to serious illness and early death – “it took the better part of sixty years in the UK to achieve a mostly smoke-free public environment” (ibid., Forward). To change people’s behaviours even with issues that directly affect their health often take decades to achieve (Ockwell et al., 2009, p.314), regardless of the evidence against these behaviours. In the case of climate change, this is time we simply do not have (ibid.)

Johnson (2013) stresses the need to provide people with “practical tools” rather than more information and he also argues that behaviour is driven by context rather than attitude.

Building on this, Lockton (2015) notes that the common approach to behaviour change assumes that:

“differences in outcome will result from changes to people—‘if only we can make people more motivated’; ‘if only we can persuade people to do this’; ‘if only people would stop doing that’ — overcoming cognitive biases, being more attentive, caring about things, being more thoughtful, and so on...considering questions of attitude, beliefs or motivations in isolation rather than in context — the person and the social or environmental situation in which someone acts.”

Public awareness and understanding are important, but they’re not enough to overcome the structural, infrastructural and social barriers that can impede or limit an individual’s ability to transition to a lower carbon and low pollution lifestyle (Ockwell et al., 2009, p.309).

The psychological phenomenon, the ‘value-action gap’ also reflects on this difficult conundrum. Flynn et al. (2009, p.1) point out that there is increasing evidence that people have become more aware of the climate crisis; however, while the public expresses a positive attitude towards environmental issues and the approval of alternative energy sources and necessary changes in behaviour, most people have not yet translated those beliefs into practical and meaningful action

to limit their own consumption and energy use or change their lifestyles. This “discrepancy between our stated values and actual behaviour is what comprises the ‘value-action gap’” (ibid.).

In the past, people’s inaction was believed to be a result of being unaware of the importance of taking action (Effectiviology, 2020). Past behavioural models assumed that raising awareness about specific topics will not only help people form attitudes and intentions with regard to those issues but also ultimately lead them to take the necessary actions to address them. Even though providing the necessary information will shape people’s values and attitudes, these then also need to be translated into intentions, and those into actions (ibid.). The more difficult it is for someone to take a given action, the less likely they will act upon it and the easier it is for a person to do an action that reflects their values, the more likely they are to do them (ibid.).

While it is difficult to identify all the reasons or drivers for why this gap exists (UK Essays, 2018), a variety of research findings point to some of the necessary steps that could effectively address this discrepancy and help in efforts of closing the value-action gap.

## 2.2 Designing environments that enable low-pollution behaviours by default

Marteau et al. (2011, p.264) explain how different environments can encourage or discourage different behaviours. The authors further explain that often the design of neighbourhoods, for example, still supports drivers instead of pedestrians or cyclists (ibid., p.264).

Shove (2009, p.1281) gives another example in the domains of urban planning and public health and argues how obesogenic environments, how active people are, how much they exercise and even their diet are “socially, institutionally, and infrastructurally configured”.

Shove further emphasises that the focus needs to be shifted from individual choice and that “the extent to which state and other actors configure the fabric and the texture of daily life” (ibid.) need to be recognised and clearly explained. She raises the idea of “envirogenic environments” that could engender the “reproduction of reproduction of variously sustainable ways of life” (ibid., p.1282).

Fuller (Tomkins, 1965) explains a similar idea about the importance of the environment we live in:

“In the universe, everything is always in motion, and everything is always moving in the directions of least resistance. That’s basic. So, I said, ‘If that’s the case, then it should be possible to modify the shapes of things so that they follow preferred directions of least resistance.’ I made up my mind at this point that I would never try to reform man—that’s much too difficult. What I would do was to try to modify the environment in such a way as to get man moving in preferred directions.”

## 2.3 Bridging the divide between bottom-up and top-down by design

Ockwell et al. (2009, p.317) offer a new approach to enabling public engagement with complex environmental issues. They (ibid., p.320) suggest bridging the divide between top-down and bottom-up approaches by using communication to stimulate societal demand for environmental regulation through advocacy and lobbying. In this way, they argue, change comes about through the public engaging with an issue and then taking voluntary, bottom-up action. But also, through them demanding that the government take top-down action, the government will more likely introduce regulations to control high carbon and pollution behaviour. They can signal to their leaders that environmental regulation is both important and desirable (ibid.).

While keeping in mind the constraints to individual behaviour change, there are many areas where individuals still have a degree of agency to reduce carbon emissions from the bottom up. For example – while demanding top-down actions from their governments through lobbying and advocacy (Ockwell et al., 2009) – people can shift to lower-carbon and pollution lifestyles, for example, by choosing to eat less meat, walk and cycle, turn the heating down and wear a jumper, compost organic waste, and fly less or not at all.

It is therefore crucial to understand the ways in which public engagement with both air pollution and climate change can be supported.

Van der Linden *et al.* (2015b) argue that key insights from psychological science should be used to inform behavioural science interventions and that it has crucial learnings to offer policymakers in managing climate change (ibid., p.758).

While applying key learnings from psychological and behavioural science, could design research raise novel questions and help closing the divide between top-down and bottom-up approaches?

Could design research be applied to design tools that stimulate societal demand for environmental regulation and enable behaviour change in reducing pollution in cities?

For design research to be able to address this gap in knowledge and improve public engagement with both air pollution and climate change, understanding some of people's core motivations, beliefs and perceptions of different environmental matters is crucial.

### 2.3.1 Changing perception & reframing narratives

In the case of climate change, Kunreuther & Weber (2012, p.1) explain that people are reluctant to pay upfront for available mitigation and adaptation measures as it is difficult for them to appreciate the delayed expected benefits of a future climate event that might happen during their lifetime. It is especially difficult for people to engage with risks of "low-probability high-consequence events" for which they have limited or no past experience and no emotional engagement (ibid., p.6). The authors argue that the investment in mitigation and adaptation strategies could be supported by "the use of choice architecture through framing and the use of default options coupled with short-term incentives and long-term contracts." (ibid. p.1).

Semenza et al. (2011, p.10) argue that

"voluntary mitigation is mostly dependent on the perceived susceptibility to and severity of climate change, and autonomous adaptation is largely dependent on the availability of information relevant to climate change and its impact."

Therefore, they suggest that climate change could be framed from a health perspective to enable behaviour change. Their findings suggest that heat waves, droughts and forest fires are threats that people more likely to act upon, especially if they are perceived as endangering their health or life (ibid.).

Whitmarsh (2009, p.418) also suggests that air pollution might be the right point of departure for linking climate change to individuals' lives and "weaving climate change into discourses of pollution" might achieve a more direct and personal effect. While Nesse and Baechler (2011, p.1) note that the "translation of abstract data into meaningful information for people to use, and tools to help them make a positive impact" might have a more enduring change. Moser and Dilling (2007) suggest that negative messages paralyse people, while positive messages and



visions surrounding climate change might connect this complex challenge to people's desires to live a meaningful life. While looking at designing behavioural public policy, Rainford and Tinkler (2011) argues that "leaders of the agenda should focus on how people can feel more empowered by changing their behaviour".

In their research Bicchieri (2010a, pp.298-300) and Bicchieri and Chavez (2010b, pp.161-162) demonstrate, for example, as to how people's perception of fairness depend on normative expectations and beliefs about what they think they "ought to do" (Bicchieri and Chavez, 2010b, p.161) in a given situation; therefore behaviour change can be supported by better understanding what people think about how others behave and how others might think they should behave in similar situations.

Supporting this argument, Goldstein *et al.* (2008) demonstrate the crucial role of norms in individual behaviour change and explain how behaviours are often dependent on the beliefs people have of what others do and what people think others expect of them. As part of a hotel's environmental conservation programme, the authors tested a descriptive normative approach in which they tested the message "The majority of guests reuse their towels", which lead to a more successful outcome in comparison to previously applied messaging, which focused merely on general environmental protection. A normative message which stated that "the majority of guests in this room reuse their towels" brought the most effective outcome (p.477). Goldstein *et al.* (2008, p.479) further argue that people "more likely to be influenced by descriptive norms when the setting in which those norms are formed is comparable to the setting those [people] are currently occupying".

As van der Linden explains (2018, p.211) descriptive norms can help inform:

"(a) people about the behavior of referent others and (b) set normative expectations about what type of behavior is 'typical' and 'desired' – reinforcing conformity with the desired norm."

In some cases, norms can also have a reverse effect. In case of energy reduction for example, when in a field experiment participants' energy consumption was compared to the average use of their neighbours, they adjusted their own use to the norm, even if that meant they started to consume more than they did previously (*ibid.*).

Global issues such as air pollution and climate change decrease people's personal efficacy as they don't believe they can make a difference. Public beliefs about the agency of and need for individuals to change and act are also affected by perceived governmental inaction (Ockwell *et al.*, 2009, p.310). Moreover, people feel that their attempts to respond to such complex issues are useless as other people are not taking action either. They often believe that the responsibility for improving environmental challenges should be a shared responsibility of society, business, industry, and government but they currently perceive that, in reality, "nobody is living up to their side of the bargain" (*ibid.*).

Promoting collective efficacy, the belief that group actions can make a difference, will encourage individuals to take action (Van der Linden *et al.*, 2015b, p.759). Or as Van der Linden quotes an article of Cialdini *et al.* from 1990, "if everyone is doing it, it must be a sensible thing to do."

Van der Linden (2018, p.211) further explains that the more people follow a desired norm, the stronger the "social signal becomes" – persuading others to further comply. In other words, the more people hear their friends, family and social circles talking about environmental issues, the more these issues will be viewed as risks that require further action. This does not only increase their perception of risk but their "intention to act" (Van der Linden *et al.*, 2015b, p.759). Social nudges are crucial as people's perceived self-efficacy – how capable people feel that they can change a specific behaviour (Bandura, 1982) – is often subject to their perception of how many others are participating and taking action (Van der Linden, 2018, p.211).

A prototypical behaviour within a group can not only increase further uptake of that specific behaviour, but also enhances the acceptance of related public policies (*ibid.*, p.212).

Perkins & Berkowitz (1986, p.962) emphasise the role of peers in regard to people's behaviours. They describe how peer influences are affected more by people's "perceptions of peer behaviours and attitudes" (*ibid.*) rather than by their peer's actual behaviour. The authors argue that the evidence that people's "perception of norms can be inaccurate" (*ibid.*) could act as a valuable insight and correcting some of these misperceptions might bring about more successful outcomes in enabling behaviour change.

Improving overall communication approaches to enhance public support for environmental regulation, Van der Linden *et al.* (2015, p.758) offer five guidelines and recommend looking at

vast and complex environmental challenges such as climate change:

“instead of a future, distant, global, nonpersonal, and analytical risk that is often framed as an overt loss for society, policymakers should (a) emphasize [it] as a present, local, and personal risk; (b) facilitate more effective and experiential engagement; (c) leverage relevant social group norms; (d) frame policy solutions in terms of what can be gained from immediate action; and (e) appeal to intrinsically valued long-term environmental goals and outcomes.”

Referring to Kahneman’s 2012 book *Thinking, Fast and Slow*, the authors suggest that public policy makers will need to appeal to both people’s analytical and experiential processing systems (*ibid.*, p.759) and describe the impacts of climate change through personal and local experiences, engaging narratives and metaphors.

Van der Linden *et al.* (*ibid.*, p.760) also explains that – as people’s daily worries overwrite plans for the future – replacing current narratives about a future and (both spatially and temporarily) distant threat with present, local challenges that are already happening in people’s immediate regions and communities might be more effective in engaging people (*ibid.*, p.761). The authors go on to describe that, as a result of “optimism bias” (*ibid.*), people often believe that these challenges are only happening to others and not to themselves. They also argue that people are “less likely to take action when losses paired with uncertainty” (*ibid.*, p.760); therefore losses that society endures at this moment in time and focusing on positive and tangible gains from action at present – instead of emphasising negative, future impacts – will both more likely to be successful in engaging people in the long run (*ibid.*).

### 2.3.2 Motivation & participation

Frey and Stutzer (2006, p.413) note that “external interventions crowd-out intrinsic motivation if they are perceived to be controlling and they crowd-in intrinsic motivation if they are perceived to be supporting”. Designing for crowding-in effect, intrinsic motivation can be supported by three factors:

“(i) Personal relationships foster intrinsic motivation. Mutual acknowledgment of one’s obligations and responsibilities is appreciated among friends, colleagues and family members. Thus, team-based or community-based structures provide motivational benefits. (ii) Communication is a precondition for reciprocity via learning about, and acknowledging the

duties and responsibilities of, other people. Communication systematically raises the intrinsic motivation to cooperate. (iii) Citizens participate in decision making. The greater the possibility to codetermine, the more the citizens would adopt decisions as their own. Participation thus raises self-determination and is a precondition for reciprocity.”

Van der Linden et al. (2015, p.761) also argue that people are intrinsically concerned about the environment and the welfare of other people, more than about being motivated by money; therefore policymakers should focus on “intrinsic motivational needs” as those can help them achieve “long-term environmental goals” (ibid.).

After reviewing insights on understanding people’s perceptions, their beliefs and motivations in regard to different environmental matters and the approaches that might enable sustained behaviour change, it is also crucial to understand through which behavioural models and strategies those insights could be applied in enabling that change.

### 2.3.3 Models, strategies and frameworks

Behavioural science is the study of human behaviour and decision making. According to Galizzi (2016) it is the “cross-disciplinary, open-minded science of understanding how people behave”. It brings together insights and methods from a variety of fields and disciplines (Galizzi, 2016):

“from experimental and behavioural economics to social and cognitive psychology, from judgement and decision-making to marketing and consumer behaviour, from health and biology to neuroscience, from philosophy to happiness and wellbeing research.”

Darnton explains (2008) that behavioural science makes a distinction between models of behaviour and theories of change. Whereas models of behaviour aid in understanding specific behaviours by identifying the underlying factors that determine and influence them, theories of change explain how behaviours can be changed and/or change over time (ibid., p.1). He further argues that while behavioural theory describes the “determinant factors underlying behaviour”, change theory supports “interventions for changing current behaviours or encouraging the adoption of new behaviours” (ibid., p.1). While the two bodies of theory have different purposes, they complement each other and therefore, understanding both is crucial in order to create effective interventions (ibid.). As Michie et al. (2011, p.1) describe “behaviour change

interventions can be defined as coordinated sets of activities designed to change specified behaviour patterns”.

While during this enquiry numerous behavioural theories and models were looked at, the final literature review is narrowed down to the ones that are specifically applied by governments, decision makers and those involved in smart cities.

The Department for Environment, Food and Rural Affairs’ (DEFRA) Framework for Pro-Environmental Behaviours (DEFRA, 2008) – applying the ABC model where A stands for attitude, B for behaviour and C for individual choice, the ‘4Es’ and ‘6Es’ policy frameworks and the Model of Pro-Environmental Behaviour (Kollmuss & Agyeman, 2002) were also looked at, but those won’t be discussed in further detail.

From the final ‘shortlist’, the thesis prioritises and investigates ‘nudging’ the most, as Nudge is still often referred to and applied both by a range of governmental bodies and especially by smart city players (The Behavioural Insights Team, 2019; OECD, 2017; Bousquet, 2017b; Glowacki, 2016; Benartzi et al., 2017; Bosquet, 2017a; Cornelius, 2017; Maheswaran & Badidi, 2018; Smets & Lievens, 2018).

Kuijjer et al. (2013, p.2) note that looking at energy use in the context of wider sociocultural practices – rather than breaking them down into isolated behaviours – might be a better way to address the complexity of these challenges.

The Energy Cultures framework studies the “interrelationships” (Stephenson et al., 2015, p.117) between people’s norms, practices and material culture, and how those are formed by external factors. Stephenson et al. (ibid.) explain the concept of culture as something helpful in:

“seeking to better understand energy behaviour because it conveys how behaviours are embedded within the physical and social contexts of everyday life, and how they are both repetitive and heterogeneous.”

Stephenson et al. (2010, p.2) argues that the framework could be applied to support the uptake of more energy efficient practices in society by utilising “new technologies, systems and

behavioural theories to assist in understanding the factors that influence the energy decisions of consumers”.

The COM-B model (Michie *et al.*, 2014, p.85) “conceptualises behaviour as a part of system of interacting elements” that involves: 1) capability that refers to both physical (i.e. skill, strength and stamina) and psychological (i.e. the knowledge and skills to perform a behaviour, and the necessary comprehension and reasoning) factors, 2) opportunity which refers to both social opportunities provided by the cultural environment and physical opportunities including “time, financial resources, access and cues” (ibid., p.86); and 3) motivation can be either reflective – involving plans and evaluations – or automatic – involving “emotions and impulses that result from innate dispositions or associative learning” (ibid.). For a behaviour to happen, capability and opportunity must be present to engage in the behaviour, and a high level of motivation is also necessary, so the motivation for performing this specific behaviour is stronger than any other competing behaviours (ibid., p.85). To change a specific behaviour an intervention might only look at the barriers with different capabilities, while in other cases it might be that greater levels of motivation are needed to enable a behaviour to change (ibid., p.87).

For certain behaviours to change all three elements need to be present (ibid.). The COM-B model forms the centre of the framework, the Behaviour Change Wheel (Michie *et al.*, 2011, p.2) around which “nine intervention functions” are gathered “addressing the deficits in one or more” of the three COM-B conditions; around those functions are placed seven categories of policy that could support those interventions to happen. Michie *et al.* (ibid., p.3) note that “interventions and policies to change behaviour can be usefully characterised by means of a BCW”.

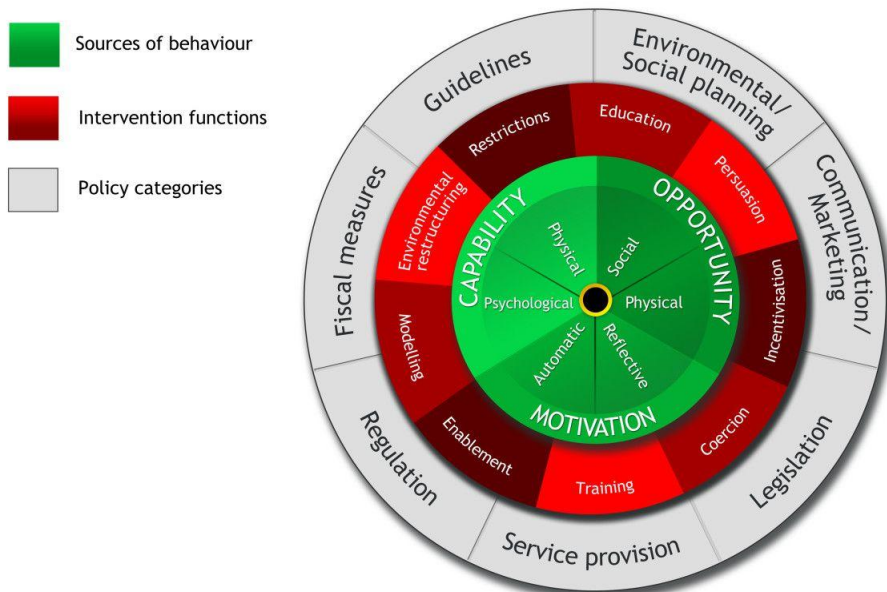


Figure 31. A screenshot of the Behavioural Change Wheel from the article of Michie et al. (2011, p.2)

While the framework ‘MINDSPACE’ (Dolan et al., 2009) was developed by UK Institute of Government and is intended as a checklist for policymakers to help them consider the most effective influences on behaviour.

<b>Messenger</b>	we are heavily influenced by who communicates information
<b>Incentives</b>	our responses to incentives are shaped by predictable mental shortcuts such as strongly avoiding losses
<b>Norms</b>	we are strongly influenced by what others do
<b>Defaults</b>	we ‘go with the flow’ of pre-set options
<b>Saliency</b>	our attention is drawn to what is novel and seems relevant to us
<b>Priming</b>	our acts are often influenced by sub-conscious cues
<b>Affect</b>	our emotional associations can powerfully shape our actions
<b>Commitments</b>	we seek to be consistent with our public promises, and reciprocate acts
<b>Ego</b>	we act in ways that make us feel better about ourselves

Figure 32. A screenshot of MINDSPACE from the Discussion Document of Dolan et al. (2009).

Dolan et al. (2009) explores how behavioural theory can help meet current policy challenges, such as how to: reduce crime, tackle obesity and ensure environmental sustainability. They explain that current tools such as incentives and information are intended to change behaviour by changing people's minds but people do not always respond to those in a truly rational way – for example, where they measure something up and make a cost-benefit analysis of their actions and then act accordingly (ibid., p.8). In contrast, approaches based on changing the contexts or the environment in which people “make decisions and respond to cues” (ibid.) - have the power to enable significant difference in behaviour. They argue that “shaping policy more closely around our inbuilt responses to the world offers a potentially powerful way to improve individual wellbeing and social welfare” (ibid.). The framework builds on nine non-coercive influences on behaviour and they claim this can be used as a quick checklist in policy making. The authors introduce three major areas of policy – “crime and anti-social behaviour; pro-social behaviour, such as voting and volunteering; and healthy and prosperous lifestyles” – in which the framework helped tackle challenges (ibid.). For each policy area they give case studies of evidence-based, innovative interventions, including: how the logic of gang membership was used to combat gang violence (applying ‘Norms’); how inertia helped them save more for retirement (applying ‘Defaults’); and how giant bananas reduced littering (applying ‘Salience’).

The authors conclude that there remains uncertainty over how lasting the impacts of MINDSPACE interventions are; that some work in “one set of circumstances” but might not work in another; and they might work well with “one segment of the population” but not with another (ibid., p.10). Dolan et al. (2009) also question how far this and similar techniques should be applied by central government and encourage them to ensure that “local and professional applications of behavioural approaches will be rigorously evaluated, and the results made available for communities to debate and adopt as they see fit” (p.10).

MINDSPACE is not without its critics either. According to Michie et al. (2011, p.2) the framework does not seem to include many of the important behavioural intervention types and it's not coherent - mixing modes of “delivery (e.g. messenger), stimulus attributes (e.g. salience), characteristics of the recipient (e.g. ego), policy strategies (e.g. defaults), mechanisms of action (e.g., priming), and related psychological constructs (e.g. affect)”.

Even with its critics, as AI assistants are becoming a bigger part of our daily lives, they offer a potentially exciting opportunity to test the non-coercive influences on behaviour in practice. Through a connected device, from the nine influences of MINDSPACE, Messenger, Incentives,



Norms, Salience, Affect and Ego – and if networked, also Commitments – could be practically tested and provide good guidance as to how to design a socially minded AI assistant skills that might enable behaviour change in the home.

In recent years, many cities and private, technology companies have been also applying behavioural science (The Behavioural Insights Team, 2019; OECD, 2017; Bousquet, 2017b; Glowacki, 2016) to “steer people in a particular direction” (Benartzi et al., 2017) and identify the principles and enablers for citizen engagement. Much of this work is focused on behaviour change and, in particular, nudging (Bosquet, 2017a; Cornelius, 2017; Maheswaran & Badidi, 2018) and be applied to smart city applications (Smets & Lievens, 2018). This is the reason why this thesis looks at Nudge at length.

# The rise of nudge - the unit helping politicians to fathom human behaviour

The government's behavioural insights team has won over sceptics in Whitehall and it is now 'nudging' behaviour across the world



Figure 33. A screenshot from an article of the Guardian on “The rise of nudge - the unit helping politicians to fathom human behaviour”.<sup>26</sup>

Through the introduction of choice architecture, Nudge – “iNcentives, Understand mappings, Defaults, Give feedback, Expect error and Structure complex choices” (Van der Linden, 2018) – draws on the insights of behavioural economics and argues that by modifying people’s choice environment, they can be “nudged into” performing behaviours that can be more beneficial not only to themselves but to other people (John et al., 2011).

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<sup>26</sup>Rutter, T. (2015). The rise of nudge – the unit helping politicians to fathom human behaviour. Guardian. Posted: 23 July 2015. Available at: <https://www.theguardian.com/public-leaders-network/2015/jul/23/rise-nudge-unit-politicians-human-behaviour>

As Benartzi et al. (2017, p.1042) put it:

“nudges do not impose material costs but instead alter the underlying “choice architecture,” for example by changing the default option to take advantage of people’s tendency to accept defaults passively. Nudges stand in contrast to traditional policy tools, which change behavior with mandates or bans or through economic incentives (including significant subsidies or fines).”

While Loewenstein and Chater (2017, p.27) welcome the idea that public policy uses behavioural insights, they also point out that the fame of nudges has had unforeseen impacts as they dominate other alternatives by which behavioural economics could and should inform policy.

While nudging can be a valuable and cost-effective tool to improve a wide range of public services (Hanley, 2018), it’s not without its critics either. Given the scale and complexity of different societal challenges, nudge and microeconomic approaches are certainly part of the solution – but they are not the whole solution.

Kippin et al. (2015), for example, warns against being overly dependent on Nudge (p.21) and they refer to the work of Jan Selby who argues that “a narrow focus on attitudes, behaviour and choices (ABC) tends to miss out on, or understate the importance of at least five things”, and they go on to list the following five factors:

- “1. Society, including social structures and norms;
2. Technologies, including infrastructures and their interaction with society;
3. International differences, and the major contextual difficulties in transplanting one successful solution to a different setting;
4. Politics, and the way political struggles and tensions often underlie social or technological changes, and;
5. History, and its interaction with social, technological and political changes”

Wilby (2010) raises another interesting point about the appeal of nudge:

“The premise is that if people act against their own best interests – by using drugs, eating junk, failing to save or taking out loans they can't repay – it is because of their individual behavioural flaws, not because of poverty, inequality or lack of hope.”

Looking at a variety of public health issues (smoking, drinking, healthier diets, etc.), Marteau et al. (2011) argue that few nudging interventions have been evaluated for their ability to achieve change in the long term (p.264). They argue that there is an absence of evidence as well as evidence of little or no effect. They note that “the appeal of nudging [for government] is self-evident” (p.263):

“[nudge] proposes a set of seemingly simple, low cost solutions that do not require legislation and can be applied to a wide array of problems arising from our behaviour. In addition, the absence of legislation holds particular appeal for governments and others wanting a smaller role for the state in shaping the behaviour of its citizens”.

Sanders *et al.* (2018, p.162) describes how in the early years of the Behavioural Insights Team they were mainly focusing on the “low-hanging fruit”, but they also hope to move beyond compliance as the only application of behavioural science. They express the hope that behavioural science could address more complex social issues (p.163), even if seeing improvements in complex problems might be “less immediate and more difficult to achieve” (van der Linden, 2018; p.208).

Next to Nudge, the strategy ‘Think’ argues that through deliberation and dialogue – given the right context and framing (John et al., 2009, p.2) – citizens can make informed and better choices about collective actions, and achieve more effective, collective solutions (ibid.). This also helps them avoid being overly focused on their “short-term self-interest” (ibid.).

While comparing Nudge and Think, John et al. (2009, pp.12-13) explains that “nudge plays to the role of the state as educator” and “the role of the policy-maker as paternalistic expert” – aiming to foster changes in people’s behaviour that are “more beneficial to them and society at large”. ‘Think’, however, believes that change is about “giving life to values that are discovered and brought out through debate and reflection” (ibid., p.14).

For the think strategy to be successful, the state needs to provide institutions that can help citizens deliberate (p.15) – an environment that “promotes listening and reasoned argumentation” (p.13) between citizens. But recommendations that develop from this process need to be followed up, otherwise participants are likely to become disempowered and “further disengaged from the political process” (p.15). The deliberative process requires greater costs compares to nudge (p.13).

John et al. (2009, p.7) further argue that equal and free public deliberation is educational as people increase their understanding of the impacts of their actions. Deliberation, however, is not only about the exchange of information (ibid.). Participants are expected to justify their preferences and perspectives in front of others, therefore a “strong motivation to constrain self-interest and to consider the public good arises” (ibid.). The authors also emphasise that the processes and norms of deliberation might not naturally emerge and need to be nurtured (ibid., p.10).

Rainford and Tinkler (2011) argue that, in contrast to nudge, with ‘Think’ it is possible to get people to consider “controversial issues in innovative ways that allows for evidence and the opinions of all to count”. They further explain that this then could be used to point to and improve those social norms and behaviours that are to be changed.

Linking the reviewed behavioural insights back to the design experiments of this PhD, Dubberly and Pangaro (2015, p.1) – in a conversation with my first PhD supervisor, Ranulph Glanville – construe “second-order cybernetics as a process for understanding and design as a conversation for action and for learning together”. They go on to describe that (ibid, p.2)

“Action may either conserve or change a situation. In other words, design is a conversation about what to conserve and what to change, a conversation about what we value. Both design and cybernetic systems involve a process of observing a situation as having some limitations, reflecting on how and why to improve that situation, and acting to improve it.”

In the design development of a new technology Van der Linden’s (2018, p.207; p.209) work on socially minded nudges can also serve as useful guidance in understanding the drivers of human behaviour. He argues that the most effective nudges seemed to be those that are socially minded – nudges that “reveal information about other people’s behaviour, raise normative expectations

about what is desirable, can be shared and transmitted online or offline and leverage social incentives that regulate individual and group behaviour” (ibid., p.207); therefore, tackling “deeply embedded social problems” (ibid., p209) will require the use of more socially minded nudges. Building further on this opportunity to apply socially minded nudges in practice, the idea of Think strategy seems to be an equally valuable guide in this enquiry. Think (John et al., 2009) argues that through deliberation and dialogue, given the right context and framing, citizens can make informed and better choices about collective actions, and thereby achieve more effective collective solutions.

These three ways of thinking – raising normative expectations about desirable behaviours (socially minded nudges), enabling collective action and behaviour change through deliberation and dialogue (‘Think’) and conceiving of design as a way to create possibilities for others to have conversations, to learn, and to act (second-order cybernetics) – will provide the basis for my design experiments.

## 2.4 Establishing my design experiments

During this research phase, I had personal conversations with two energy experts, Dr Sarah Darby (Associate Professor and Acting Leader, Lower Carbon Futures Team, Energy Programme, University of Oxford) and Geoffrey Stevens (Technology Innovation Manager at the Future Cities Catapult, previously Technology Manager at the Energy Saving Trust).

Both Darby and Stevens described how they had been working on projects aiming to engage consumers in more sustainable energy behaviours in the home, some with more success, some with less impact. Stevens explains that it is not because people don’t care about the environment; it is more that “people are overwhelmed with information and their day-to-day life in general, and they simply forget about their energy use” (notes from a personal conversation). The current modes of feedback (e.g. bills, smart meter data, etc.) are not salient enough in their day-to-day activities. By the time they get that feedback, they have already forgotten about the associated behaviour.

Stevens believes that “a right advice at the right time”-approach could have a greater impact on energy behaviours. He envisions a solution that provides users with a small reminder of their behaviour at the moment they perform it (such as a message, sound, email, etc.) along with

information about the context of that behaviour. For example, “reducing your thermostat by 1°C would reduce the carbon emissions produced from heating your home by 10%” (Hannah, 2018).

During our discussions, Stevens introduced me to the Carbon Intensity API<sup>27</sup> and the UK ‘gridwatch’, a website that shares data on the National Grid’s real-time status. For several weeks, he then sent me a message every day in the morning and in the evening during peak hours – reminding me that the grid was overloaded and that I should avoid using the kettle, dishwasher or other electronics.

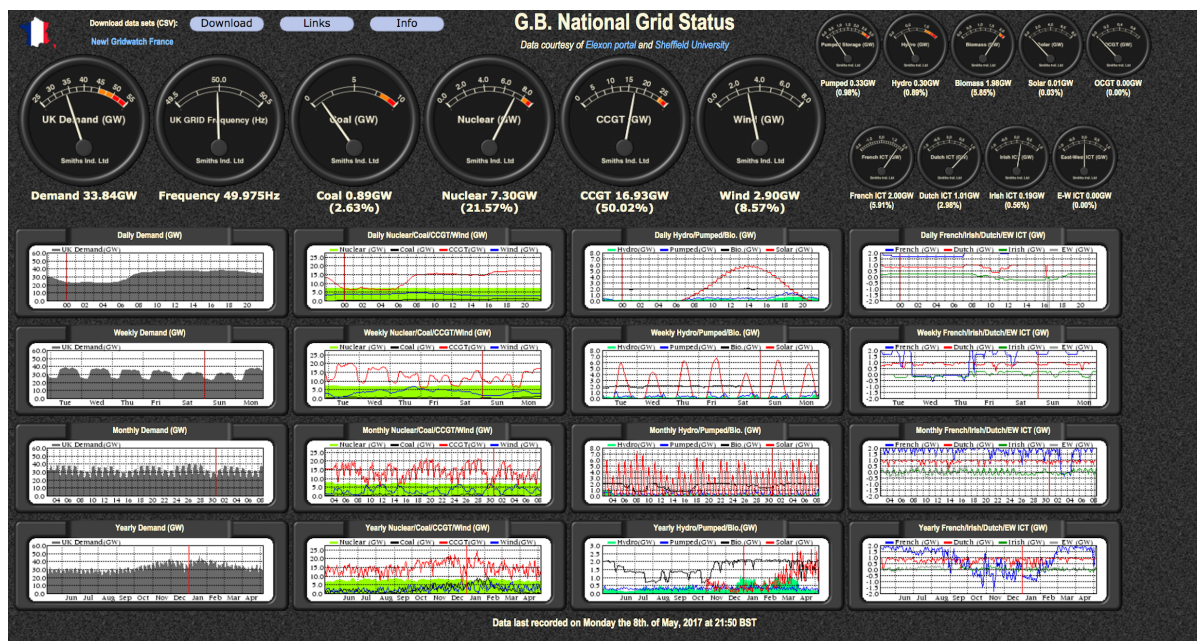


Figure 34. A screenshot from the website of the UK’s National Status (‘Gridwatch’) that provides real-time data on the UK’s national grid status.<sup>28</sup>

This experience called to mind my childhood, when my mother would nag me about forgetting to wash my dishes or switch off the lights when I wasn’t in my room. When Stevens stopped messaging me, I noticed that I continued to think about the grid and started avoiding behaviours that would consume power during peak demand. The reminders were still playing in my head, even if he wasn’t messaging me anymore. It made me wonder whether I could design a technology that would provide similar reminders about pro-environmental behaviours.

<sup>27</sup>Carbon Intesity API (2020). Available at: <https://carbonintesity.org.uk/>

<sup>28</sup>Gridwatch (2020). Available at: <http://www.gridwatch.templar.co.uk/>

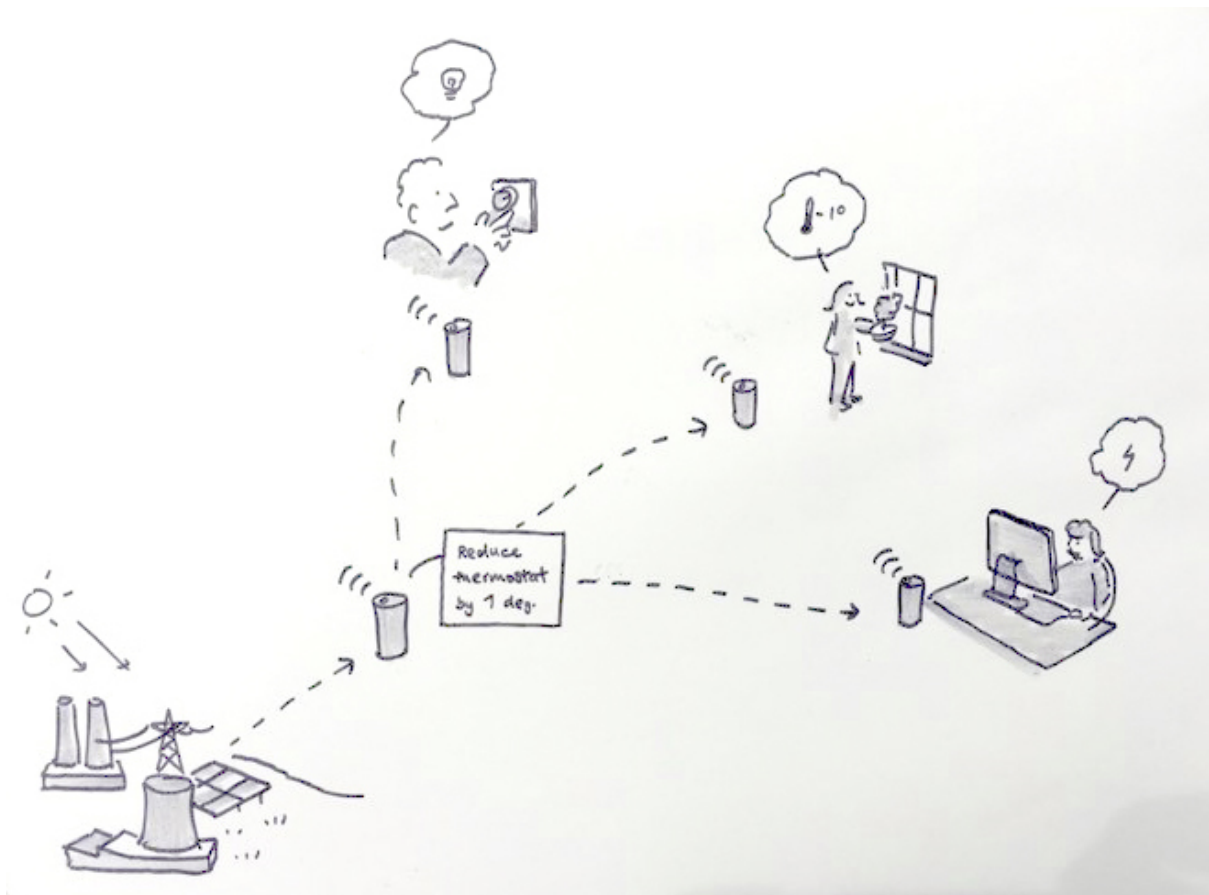


Figure 35. Sketching the idea of how AI assistants could be designed to send out a 'trigger', a call-to-action and ask everyone in the network to reduce e.g. their heating with just one degree to reduce the demand on a grid. This could be applied to all sorts of behaviours, e.g. water use or air pollution reduction challenge

To test Stevens' hypothesis, I set out to design a technological experiment that would encourage people to reduce their heating by 1°C as my first project. By designing an intervention that aggregates small, individual change through a network of connected technologies, I believed that I might be able to scale up individuals' agency and circumvent policy change. Rather than designing and investing into the development of a new system or device, I decided to piggyback onto an existing system and network that already has a large community of users.

Given their growing abilities, AI home assistant devices offered a potentially exciting opportunity to design the first experiment.



## Chapter 3. The first two design experiments and research through design

With a research through design process, Chapter 3 describe two practice-based experiments that were conducted to investigate digital assistants in the home and their potential for supporting the uptake of new behaviours that could reduce participants' social and environmental impact. All experiments are based on research methods of participatory design and action research.

In the words of Frayling (1993, p.5), “development work” in which “a piece of technology” is customised to “do something no-one had considered before, and communicating the results”, and action research are both conducting research through design. Godin and Zahedi describe research through design “as an approach to scientific inquiry that takes advantage of the unique insights gained through design practice to provide a better understanding of complex and future-oriented issues in the design field.” While Zimmerman argues that research through design is “the process of iteratively designing artifacts as a creative way of investigating what a potential future might be” (2010, p. 313).

A research through design process led this PhD in the investigation of how potential new, more socially and environmentally minded, uses of current AI assistants could be designed in the future. Through close collaboration with participants in their homes and the ongoing iterations of the experiments, new qualitative insights are gained into the inner workings of these technologies and the assumptions built into smart home applications about human behaviour.

### 3.1 The rise of AI assistants

Artificial intelligence (AI) assistants - also known as digital or virtual assistants - are software agents that can perform tasks or services on someone's behalf. Designed to interact with people, these devices may possess human-like qualities, such as natural language understanding, speech and facial recognition, or even mobility.

#### 3.1.1 Growing Abilities and Influence

One of the earliest devices that might be called a digital assistant was IBM's first speech recognition machine, the Shoebox (See Figure 4.8). As IBM archives explains, the device, introduced in 1962, could recognise 16 words and was capable of making simple calculations.

Using a microphone, an operator could dictate numbers and commands, such as “five plus three plus eight plus six minus nine, total,” and the machine would print out the correct answer (IBM100, 2019).



#### The Shoebox

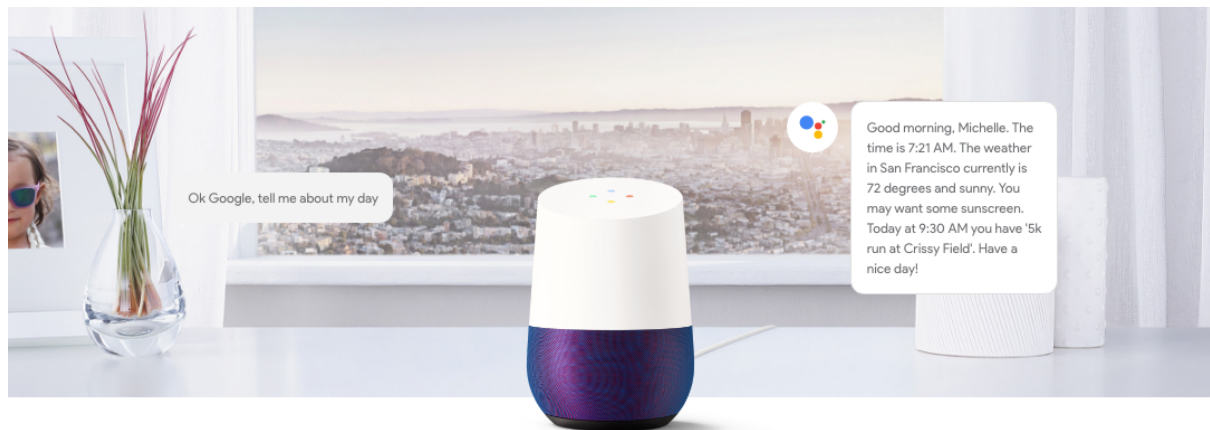
*William Dersch's Shoebox listened as the operator spoke numbers and commands such as “Five plus three plus eight plus six plus four minus nine, total,” and would print out the correct answer: 17.*

01/04

*Figure 36. A screenshot from IBM's website of the IBM's Shoebox: “Introduced in 1962, this early speech recognition device could understand 16 words: zero, one, two, three, four, five, six, seven, eight, nine, minus, plus, subtotal, total, false, and off.” (IBM100, 2019).<sup>29</sup>*

Just over fifty years later, today's voice-based AI assistants are capable of answering a variety of questions about people, geography, history, music, sports, and more. They can also learn from their users. The more time AI assistants spend with their users, the more data they collect to learn from, and the smarter they get (Anders, 2017).

<sup>29</sup>Pioneering Speech Recognition. IBM 100. Available at: <https://www.ibm.com/ibm/history/ibm100/us/en/icons/speechreco/transform/>



Plan to do more.

Get personalized help managing your schedule, commute, and more whenever Google Home recognizes your voice (with your permission, of course). Plus, make calls, set timers, and get information on the traffic to work.

Figure 37. A screenshot of Google Home

### 3.1.2 Beyond Pizza, Taxis and Weather Forecasts

At a public event in 2017, Amazon CEO Jeff Bezos said that ‘AI is in a golden age’ and solving problems that were once seen as science fiction<sup>30</sup>. Whilst this may be true behind the scenes at Amazon, the current use cases for AI assistants — like Amazon Alexa, Google Home and Microsoft Cortana — are much less imaginative. Designed primarily for home automation, home entertainment, and shopping — they offer their users services like ordering a pizza, calling a taxi, or playing their favourite music.

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<sup>30</sup>Kharpal, A. (2017). A.I. is in a ‘golden age’ and solving problems that were once in the realm of sci-fi, Jeff Bezos says. Posted: 8 May 2017. Available at: <https://www.cnbc.com/2017/05/08/amazon-jeff-bezos-artificial-intelligence-ai-golden-age.html>

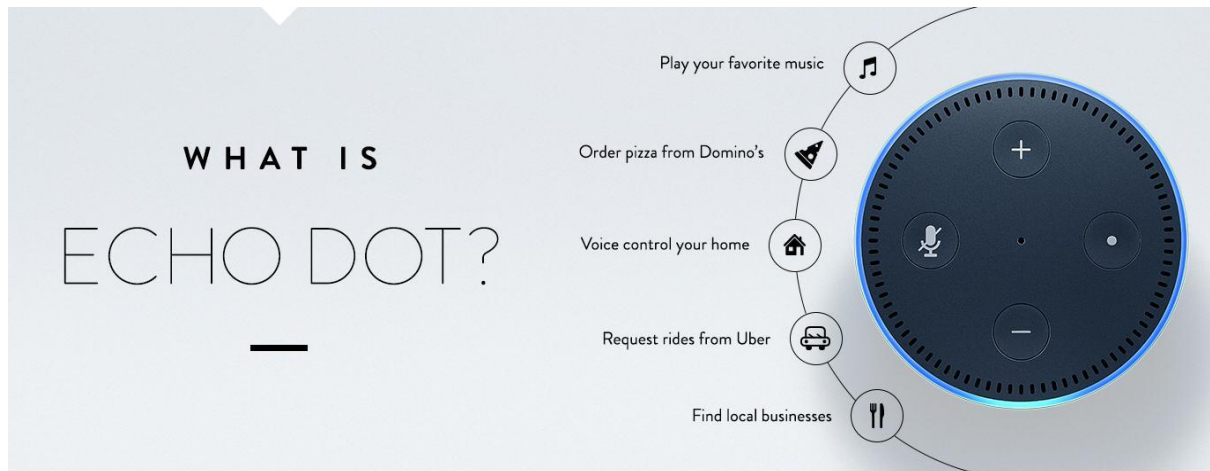


Figure 38. A screenshot from amazon.com of Amazon's Echo Dot that "helps you play your favourite music, order pizza, request rides from Uber..."

Designing a good VUI requires specialised skills such as computer science and linguistics. Still, there is an opportunity for designers to explore how AI assistants might be used for different, more socially and environmentally minded purposes, while keeping in mind that the devices still have considerable technological limitations.

## 3.2 Project # 1: Getting to Know Alexa

Developed by Amazon, Alexa is a cloud-based artificial intelligence that acts as the brains behind a family of smart speakers, such as the Echo and smaller Echo Dot. These devices allow their users to initiate automated services or processes using their voice.

The Alexa Skills Kit (Amazon, 2019) is "a collection of self-service APIs, tools, documentation and code samples" that make it relatively straightforward for a developer to create their own Alexa skills (Amazon Alexa, 2019). Developers can also use the 'Smart Home Skill API' to teach Alexa how to control various smart home devices, such as light bulbs and thermostats. By developing a skill of my own for Alexa users who are interested in shifting to lower-pollution lifestyles, I realised that I could reach out to a much bigger audience than if I were to develop a purpose-built system of my own.

### 3.2.1 Project Description

Connecting my Alexa to the live data of the UK's National Grid, I aimed to test whether I could encourage a small community of Alexa users to reduce their energy consumption or at least tweak their behaviours during peak hours – when the energy grid is overloaded (addressing

Anderson’s opportunities for near-term mitigation relating to 7. demand-side response in Chapter 2. p.70).

Using a software called Twine – which is an open-source tool for telling interactive, nonlinear stories – I began writing scripts that would form the basis of my Alexa skill conversations – relating to different home appliances and behaviours – and the AI characters. This logic was then built into the code later on by a developer, Rebecca Jones.

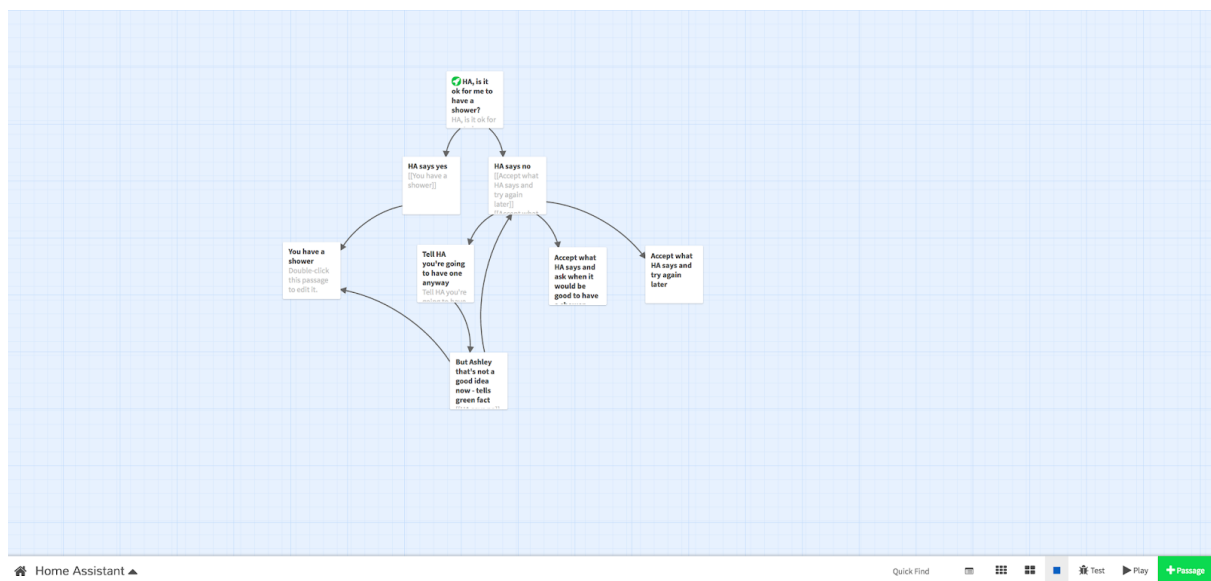


Figure 39. Writing the stories and possible conversation-branches in the software Twine (see a legible version in Appendix 2.), which are then encoded into Alexa’s energy skill

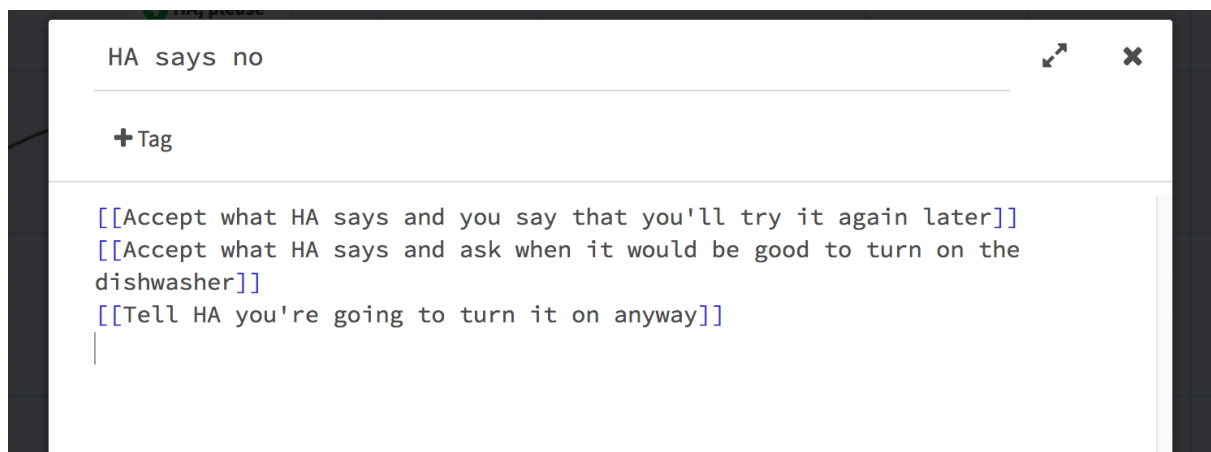


Figure 40. Different conversation-scenarios between a participant and Alexa (called Home Assistant – HA – in Twine) that might happen and therefore different conversation-scenarios need to be encoded in the interaction with the HA in advance (see full conversation sample in Appendix 3.).

I conducted these experiments from December 2016 to May 2017. In real life the possible

number of conversation-threads between a person and their AI assistant could be infinite. As a start, a dozen different threads of speculative conversation scenarios were developed in the code. I then connected all my domestic appliances through smart plugs to an Alexa Echo Dot.

Although in the beginning of the thesis I set out the research to look at air quality, I felt that the behaviours would involve broader sustainability and environment-related challenges than solely air quality; therefore I gave a ‘working title’ to my Amazon skill: “Climate Pal”, or CP for short. In running the very first experiment to develop the different characters, I was mainly interested in how comfortable I would feel handing over control of my appliances to an AI. And how annoyed I would become over time, having to negotiate with the app every time I wanted to use one of my appliances.

Developer, Rebecca Jones and I developed these three different characters to serve as prompts, so I could customise and discuss with my prospective participants what they would prefer their home assistant to sound and be like.

The possible actions, questions and answers were operating on three AI characters: a “light, medium and hardcore environmentalist” (see the samples of the code in Appendix 4).

```
},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    //speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
    speechOutput += "Are you sure? I really don't want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the heating on...";
  } else if (this.attributes['rebelCount'] === 2){
    //speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
    speechOutput += "Hmmm, this is very disappointing. I don't know what to say.";
  } else {
    //speechOutput += "You are being very persistent.";
    speechOutput += "Hmmm. OK. If this is really necessary... but as punishment let me play some Spice Girls for you...";
    //this.attributes['rebelCount'] = 0;
  }
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"PoliteResponse": function(){
  //var gridvalue = gridcheck();
  //var speechOutput = "You're welcome. Would you like to know anything else?";
  //var repromptSpeech = 'Please say that again?';
  //this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
  this.emit('AMAZON.CancelIntent');
}
```

Figure 41. A screenshot of the code of the hardcore environmentalist AI. The user asks to switch on her appliances in peak hour, which the AI refuses: “Are you sure? I really don’t want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the heating on...”

Based on which personality the user downloads to the Echo Dot, Alexa would be more or less likely to intervene with the user’s decisions. The fine tuning of AI characters was limited by what was possible to ‘translate’ into an algorithmic conversation. For example, if you downloaded the

strongly environmentalist skill, Alexa’s algorithm runs by only one rule — save energy in the home during peak hours whatever happens, whatever the user wants. The stronger environmentalist the AI is, the more times the algorithm repeats the same advice in peak hour.



Figure 42. Follow this link to see one of my conversations with my CP app in peak hour. Available at: <https://vimeo.com/231939891> (Vimeo password is: Alexa).

### 3.2.2 Limitations and findings of the first experiment

Through repeated testing of my Alexa Echo Dot and with its current technological limitations, I soon realised that it was not possible to develop meaningful and engaging conversations with the device.

In building an Alexa skill, I also realised that Alexa is a more closed system than I originally thought. At the moment, Alexa can only be triggered if the user starts a conversation by saying the name “Alexa”. With this limitation, it seemed that there would only be a remote chance that my prospective participants would engage with the device and start a conversation about sustainability (e.g. “Alexa, is this the right time to switch on the dishwasher?”, or “Alexa, have I showered already more than 5 minutes?”).

In addition, remembering Stevens’s idea of giving “the right advice and context to people at the right time”, this approach seemed like the wrong way to test my hypothesis. In contrast, what I aimed to achieve was to enable Alexa to be triggered by the different sensors and behaviours that



were being monitored in the home in real-time. In this way, the device would be triggered by a participant's given behaviour in the home and reminders would be automatic.

After a few trials with Alexa to design this automation, I realised that I couldn't access Amazon's code to connect it to my set of connected sensors in the home. Unfortunately, this also meant that I had no way of evaluating the impact of my experiment. For the intervention to work I therefore needed to build my own home assistant device from scratch.

Realising that I wouldn't be able to develop on or work with an existing home assistant AI, I needed to adjust my research scope to answer my research questions and to use the level of sophistication needed. Unable to use Alexa's code and develop a conversational AI of my own, I was unsure how to approach my second experiment. Without the AI element, I worried that the device would be reduced to a one-way informational tool, rather than one that could initiate a conversation as I had originally intended.

### 3.2.3 Reflections on my own role in the experiment

Most importantly though, I became really concerned that my Alexa skill would be yet another "persuasive technology" project - the same approach that I had been critiquing from the beginning of my research. I was building a closed system in which the goals needed to be precisely encoded into my algorithms – based on the set of rules that I believed would achieve 'desirable', preventative behaviours. I fell into the same "trap" as many designers of top-down, persuasive technology interventions, who are often unable to achieve sustained engagement with their participants (Brynjarsdóttir *et al.*, 2012). Here I was also reminded again of Mazé's (2016b) question about the designer's bias and how the designer is responsible for founding or opposing how sustainability is defined and "in what ways [sustainability] becomes practiced, normalized, and institutionalized" (Mazé, 2013, p.10).

With all the learnings and technical limitations of my first experiment, and without a two-way interaction and a meaningful conversational-AI element, I decided to move on and take a different approach to answer my research questions. In May 2017, I started my second experiment.

In my second project I set out to build a digital storyteller that used pre-recorded audio files. A digital social companion that would tell stories and recommend practical actions about



sustainability in relation to participants' real-time actions in their homes, complement and interrupt their day-to-day activities. This idea was based on my initial experience of receiving text reminders from Stevens.

### 3.3 Project # 2: Becoming an AI

To enable more nuanced conversations with my participants and develop sketches for the best possible version of CP, I needed to operate with a very different mindset. Rather than imposing on people what they should do, I decided to have a conversation with them first. I needed to better understand them to be able to design a system and interaction that could best assist them.

In that way, I might better understand what they want to conserve and what they want to change in their current behaviours – about what they value and prioritise in their daily lives and what activities they might be willing to change, if any. Instead of making my participants follow a set of prescribed behaviours, I decided to open up the discussion and offer something more like a 'carbon bank' or 'personal carbon allowance'<sup>31</sup> - where they could negotiate activities on their own, with a weighted carbon footprint for different choices.

This line of thinking raises the question: if Alexa doesn't allow me to build a system with open-ended conversations, how could I design one that would? To move beyond a pre-set, quantified approach to develop this experiment, I realised the best solution might be if I myself became an AI assistant. In this way I can observe, reflect on, iterate and refine my ideas for the future CP system. And most importantly, this observation and reflection will also help me realise some of my own assumptions and biases about these challenges.

As Balint (2016, p.88) notes on first-and second-order cybernetics:

“Engineers create a world that typically relies on first-order change, where the goals of the observed system are set and the observer in the inner loop is closely coupled with the goals of the system. The regulator of this system is (supposedly) not changed by the observation.

Designers are explicitly coupled with the system through an observing paradigm, and they can

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<sup>31</sup>As Carbon Trust (2012, p.8) explains: “similarly to Nutritional Guideline Daily amount (GDA) – the amounts for the daily intake of calories and nutrients recommended for women, men and children – the personal daily carbon allowance (which could be expressed as a Carbon GDA) would be to provide a guideline daily amount of carbon that should not be exceeded. The assumption is that consumers could use this information to establish an environmental context for their everyday consumption habits.”

modify the goals of the observed system. Designers, architects, and artists can create and invent new rules, thus broaden the system's paradigm by adding variety to it. This leads to new perspectives and can lead to novel outcomes beyond what an existing paradigm can accommodate."

I was deeply inspired by the 2016 PhD thesis of Fantini van Ditmar who in "Becoming Your 'SMART' Fridge" took on the role of "a smart fridge software and collecting both quantitative and qualitative data" to question the algorithmic logic behind IoT technologies (Fantini van Ditmar, 2016, pp.124-125).

Fantini van Ditmar looked at "how human lives are represented within the quantified approaches of 'smart' technology" (Fantini van Ditmar, 2016, p.1) and characterised this as "the Algorithmic Paradigm" (ibid.). She wanted to understand the logic behind algorithmic conversations and explored "questions of how complex, lived, human experience is oversimplified in the IoT".

By bringing second-order cybernetics into design research, in the context of the Internet of Things, her work emphasises the importance of the "observer", that "smartness is relational" and calls for "a shift in perspective to create more meaningful interactions with devices in the smart home" (ibid.).

When developing the Alexa Echo device, Amazon engineers initially faced major challenges with lag. When you asked Alexa a question, it could take two or three seconds for her to respond. To get around this problem during the testing phase, the Echo engineers relied on a human-computer interaction technique called the Wizard of Oz (Bella & Hanington, 2012, p.204). Instead of building a working AI, they convinced users that they were interacting with an AI, which was actually being operated by an unseen human being.

As Kim (2016) describes, "a human 'wizard' [sat] in a separate room and [responded] in real-time to any voice query that a human testing subject would make to the Echo, often without telling the tester in advance".

Following in Fantini van Ditmar's footsteps and applying the Wizard of Oz interaction technique, I started to develop the second experiment. Since I couldn't be certain whether my participants would own an Alexa-powered device, I needed to find an alternative device. The most practical choice was the current ubiquitous technology - the smart phone. The same way as

Stevens reminded me to switch off the lights and kettle in peak hours through text messaging, I wanted to recruit participants who would be up for exchanging messages with an ‘AI’.

### 3.3.1 Finding a Suitable Technology for My Conversations

Seeking to find a solution in which I could somehow ‘sound like an AI,’ I joined the Amazon Developer community and got access to Amazon Polly, a lifelike text-to-speech web service. I then set out to communicate with my participants by sending them audio files via WhatsApp. To take into account the current technological limitations of home assistant algorithms, I started testing whether I could send pre-programmed answers to multiple situations reflecting to multiple conversations with multiple participants (as an AI would). Therefore, I started recording pre-written audio messages.

### 3.3.2 Finding the Tone of My Messages

I also needed to decide on the tone of my messages. After reading numerous papers from Darling and others (Darling, 2017; Breazeal, 2003; Chang et al., 2013; Darling et al., 2015) discussing “the effects of encouraging or discouraging people to anthropomorphize robots through framing”, it became clear that this would be one of the most important questions in my experiments. Would a more familiar, friendly CP encourage better engagement with my AI or should it stay very limited in its expressions and language? Calling it a ‘pal’ - at least in my head - had already implied something friendlier. This raised a range of complex and challenging questions:

- What kind of character/persona should be designed?
- Should the participants decide on its persona and create their own pal?
- What else – apart from the voice – would constitute a persona, that might be important in the success of the interaction?
- Should a visual element be added to the design?
- Moreover, should the participants know that I am effectively hiding in the machine?

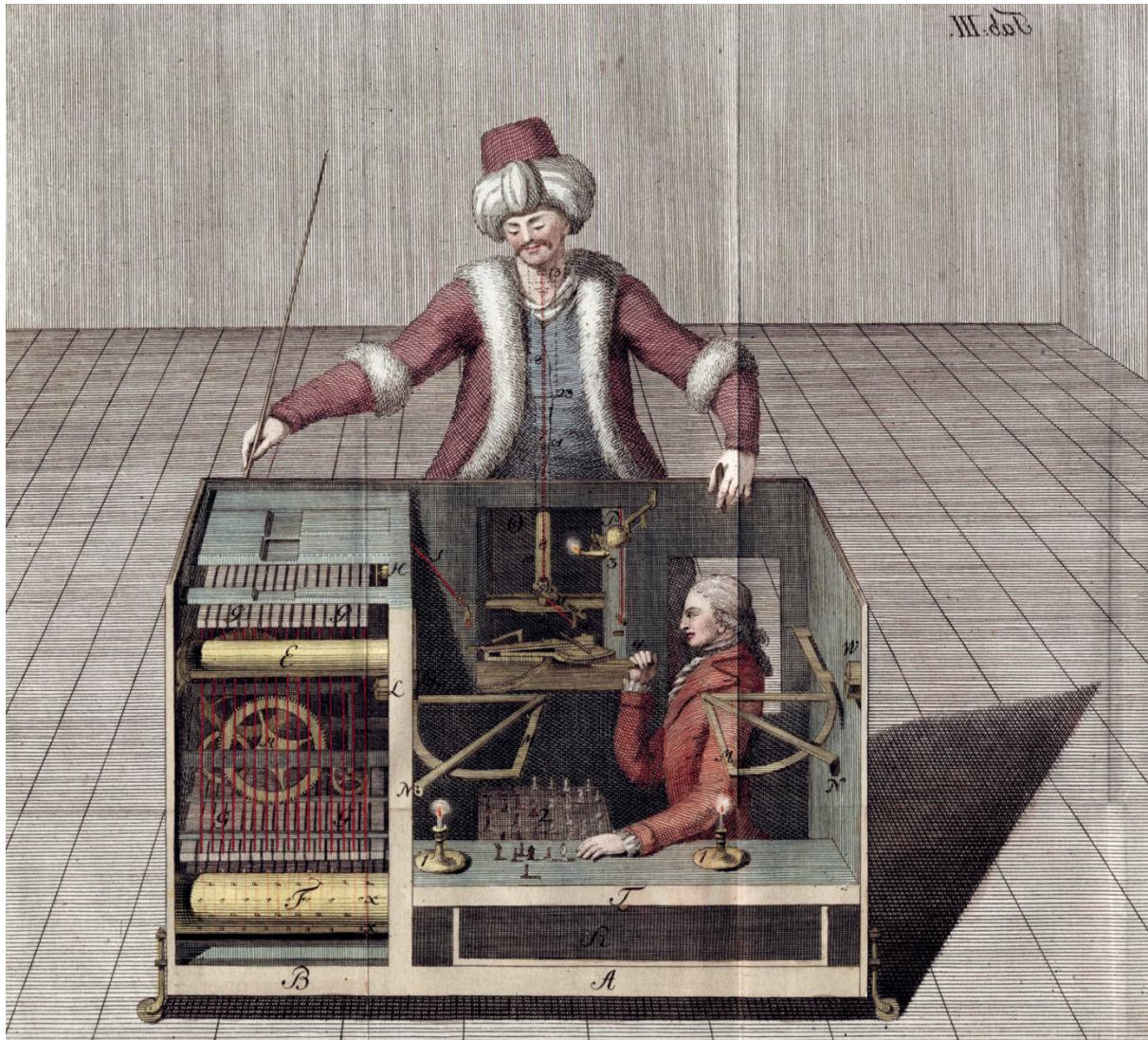


Figure 43. *The Turk*, circa 1820. Photo © Joseph Racknitz, Public domain, via Wikimedia Commons

Darling (2016) explains that “people tend to anthropomorphize robotic technology”, treating machines as though they are alive, while knowing they are not (p.2). She suggests that one of the tools we can use to promote this anthropomorphism is framing. She explains how personifying a robot through a name or, for example, providing a backstory to it, affects how people respond to robots.

For example, there are reports of those served in the US military who suffered emotional stress after their robots were destroyed in combat or disarming landmines (Garreau, 2007; Garber, 2013). In cases like these, Darling (2016) argues that designing lifelike qualities onto robots is undesirable, as the emotional attachment can hinder the intended use of the technology (ibid.,

p.4). Keeping this in mind, I started to look into cases where anthropomorphism actually enhanced the acceptance and use of a robot.

Darling further refers to other people's research to highlight three important insights: referring to 1) Cynthia Breazeal's work on digital social companions, she argues that "social robots are meant to partner with humans and should be designed to support human empowerment" (ibid., p.6), to 2) Kidd's 2008 findings on how people who trying to lose or maintain weight will track their data for nearly twice as long when using a social robot compared to a computer or paper log method" (ibid., p.5); and lastly she refers to 3) Fasola and Mataric (2012) argument that praise and companionship can be good tools to motivate people to exercise more. These positive examples of social robots encouraged me to continue exploring the potential of AI assistants. In the case of CP, however, there is the added challenge of only having a voice-based interface. The interaction with CP will only embody human qualities and features through her speech, language and voice.

### 3.3.3 The tone, frequency and format of my messages

Through the Amazon Alexa Voice Design Guide (2018) I learned about the four key elements of conversations to remember when designing conversational experiences:

"1) context (i.e. everyday conversations take many things into account besides just the words we speak, including why, when, and where we converse), 2) engagement (i.e. conversations are dynamic and require both parties to understand, respond, and then remember what the other participant is saying), 3) tone (i.e. face-to-face conversations are filled with personality, emotion, and even surprises; you never know what someone is going to say next; incorporating these quirks can make interacting with Alexa feel more like having a conversation) and 4) memory (i.e. conversations need to build on previous questions and answers, and account for prior context to make the conversation more engaging and relevant to the user)."

Developing or researching how to develop an engaging voice character for the device was not within the scope of this PhD. The experiments applied existing AI voices available in the Amazon Polly library.

To define the right tone, format and frequency of the messages I collaborated with a professional usability tester, UX researcher and cultural anthropologist. Given her experience developing hundreds of apps and interfaces over the past 20 years, I thought she would be the perfect person to help me set the right tone and frequency for my messages, and also to set up the experiment and recruit participants in the most professional and unbiased way.

First, we agreed that she would send a few lines on describing her daily activities. I didn't want to conduct an in-depth interview or shadowing her, as I wouldn't be able to do this with anyone else who might download the CP skill from the Amazon Skill Store. As I still needed to start writing up my questions, this was a good basis to understand her daily routine (see Appendix 5).

Using her schedule as a basis for my prospective conversations, I wrote and pre-recorded a selection of phrases, questions and responses for CP; some of the simpler and more complex ones (see Appendix 6.)

- Thank you.
- Hmmm, that sounds great.
- Good plan.
- How about another day?
- I think that's brilliant.
- Well done.
- Congratulations.
- Hmmm, I need to think about this for a moment.

*Figure 44. Some of the pre-recorded responses to a possible conversation-flow*



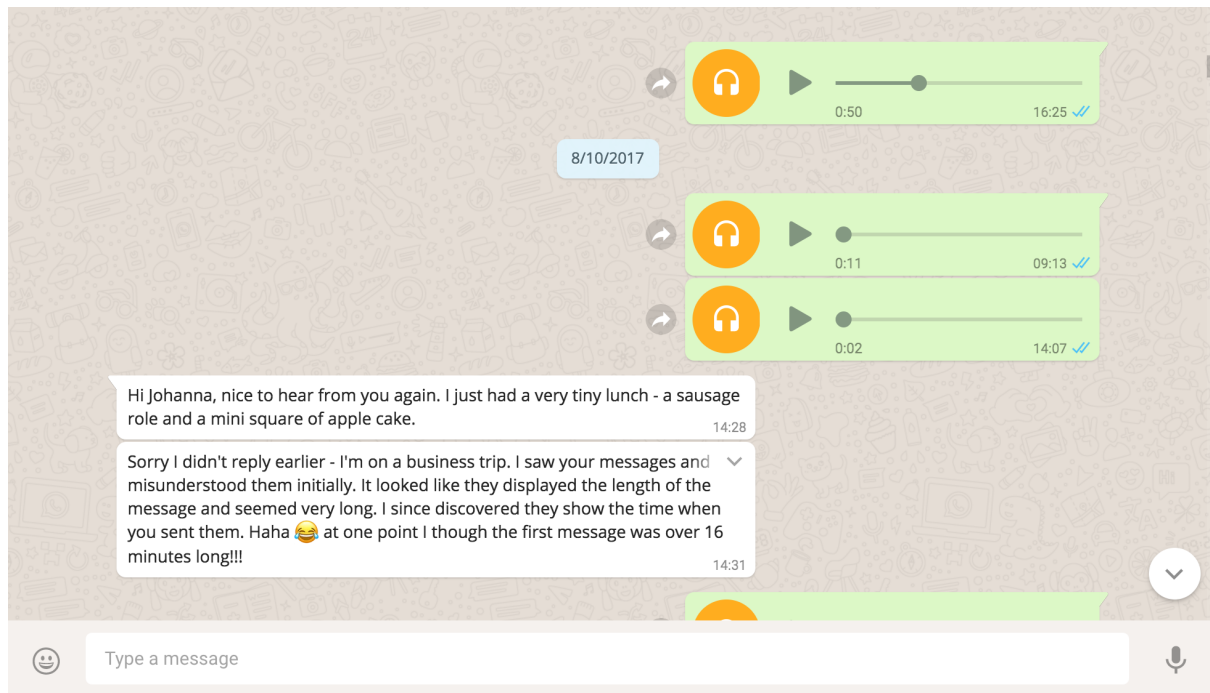


Figure 45. WhatsApp conversations between AI assistant, Johana and UX researcher

After pre-recording the audio files, I started my first conversation with the UX researcher. Our experiment lasted for two weeks. I aligned my daily routine to hers and started to get up at 5:30 am like a ‘good assistant’ would do. I asked the UX researcher to choose from the AI voices available on Amazon’s text-to-speech library. She chose the character, Johana to have conversations with.

### 3.4 Findings of my second experiment

During the experiment, the UX researcher was sending me feedback about the overall experience, the frequency and tone of my messages, so I could iterate my messages and suit her lifestyle better. She also explained that she had time messaging me mostly during her commute to work and on her way back home, and in the evenings. She didn’t have time to reply during the weekends. The UX researcher also mentioned that while she wanted to send me audio replies, she was usually in public spaces and felt shy about speaking to the AI in public. For this reason, she only sent text messages in the end.

After this experiment, I wanted to start talking to a bigger group of people. The UX researcher helped me recruit a random group of participants whom I didn’t know. She helped me write a screener that outlined what kind of people we were looking for. We aimed at recruiting people who were already using Alexa, as they were the main target audience of this investigation and

those who had a degree of interest in or understanding of air pollution and climate change. Within the group she chose an even split of gender, age, socioeconomic background. The UX researcher used a 'snowball system' to recruit participants asking anyone she knew if they had an Alexa or friends of hers with an Alexa, or similar home assistant devices.

The experience was very different and varied from participant to participant. One person was working from home and he liked receiving messaging anytime of the day and more frequently - even on weekends. Another one could only reply in the evenings or very early mornings.

All participants were interested in different aspects of environmental challenges and daily actions. They all had very different knowledge and perceptions of air pollution and climate change. And whilst this made the conversations much more interesting, it turned out that I could only repeat the same, pre-recorded audio messages a handful of times; the conversations and reactions from participants were so varied that I needed to reply to almost every interaction with new recordings. Due to the effort involved in maintaining these conversations, I was only able to have four participants at a time.

To apply the behavioural insights that I learned through the literature review (see in Chapter 2.) in practice, I set out to look at descriptive norms and how their effectiveness could be tested in the interaction with my participants. Supporting the argument of Goldstein et al. (2008) who explains how behaviours are often dependent on the beliefs people have of what others do and what people think others expect of them to do – and also van der Linden's points on (2018, p.211) descriptive norms that can help set “normative expectations about what type of behaviour is 'typical' and 'desired'” – provided valuable guidance in phrasing my messages.

Click on the links below to listen to a short sample of a conversation between Johana and the UX researcher from the above screenshot (see the rest of the conversations in Appendix 7.)



Johana:

*Good morning. No worries at all. Whenever you can reply, it always works for me. I am really here for your service with low-carbon transition. It's good that you're back home. It sounds that you had an intense business trip. Try to relax while working from home. It looks like we will have a sunny day. One more thing: I'd like you to think about a few, more philosophical questions today. The first one is: if you think of the word 'Earth' or 'Planet', what are the first things, images or feelings that come into your mind? Could you describe them? Please take your time. You can reply anytime during the day by sending a text or voice message. Have a lovely morning.*

Figure 46. You can listen to a reply sample to [Participant 01's message here](#) (after opening the sound files please wait a few seconds for the file to load)

Participant 01:

So nice to get these 😊

Johana:

*I see you're sending smiling emoticons. I am pleased to read that you are happy about our experiment. I can't smile as I am a voice user interface, but if I could, I would smile back. I also wanted to inform you that I gave you a name: A001. As you are my first friend on Earth. But as soon as I have more friends, I will need to start naming them. I hope you'll like this name. I tried to be creative coming up with it. Enjoy your morning, A001!*

Figure 47. You can listen to a reply sample to [Participant 01's message here](#) (after opening the sound files please wait a few seconds for the file to load)

During the experiment my participants all provided feedback and recommendations on how their experience could be improved. Their preferences were varying greatly, even with four people participating in the experiment only. Some patterns were noticeable in their recommendations though:

- Shorter messages tend to be more effective in the threads of our conversations (usually I kept the length of messages below 50 words);
- Shorter messages were more likely to be listened in full (two of my participants didn't have the time to listen to some of the longer messages, because they were in a rush to work or picking up their kids from nursery); and

- A series of tailored, brief messages were more effective than longer, more comprehensive ones (three of the participants preferred to receive action-oriented messages with clear suggestions on what to do about given behaviours)
- Overall participants preferred messages that provided them with a broader context of why they should change a specific behaviour (e.g. how water use relates to heating and that to energy use)

Some of these insights were consistent with the existing research, which shows that cognitive resources are limited (John et al., 2009, p.4). Many of my participants reported that they simply forgot about the messages or that they were too distracted by other things in their life to properly consider them before acting or performing certain behaviours. These insights raised numerous questions (see Appendix 8.) that needed to be addressed in further iterations of CP. To name but a few, this includes:

- How important is this issue to my participants?
- How do my participants formulate and make decisions?
- What behaviours should CP promote?
- What are the conscious and unconscious drivers of these behaviours?

### 3.5 Limitations of my second experiment and reflections on my own role in the experiment

Perhaps the most important insight I gained from the second experiment was that I had made Johanna too smart. By putting myself inside the machine, I gave her capabilities (such as humour, memory, and a tone of voice) that exceed the current limitations of present-day AI assistants. Participants reported to the UX researcher how they slowly became more emotionally engaged to their digital assistant. If my participants had been interacting with a real AI, the experience would have been much different. Being the human behind the AI, this experience reminded me to programmes that were going through the Turing test – Eliza who was imitating a psychologist, Perry who was programmed to imitate a paranoid schizophrenic, Catherine who focused on talking about Bill Clinton and Eugene Goostman who was given the persona of a thirteen year old Ukrainian, so judges testing it interpreted the programme’s non sequiturs as cultural and language barriers (Gendler, 2016) – which all sounded incredibly human. While their conversations couldn’t be easily distinguished from a human’s, the lack of consistency in their

personalities and their inability to deal with brand new topics were strong giveaways. In contrast to these computer programmes, as I was taking on the role of an AI myself, I was able to respond with brand new content each time when a new topic or question arose, as well as provide the consistency of my personality. And in this sense, my second experiment exceeded the limitations of current AI home assistant devices. To be a more valid test of such a device and its potential for enabling behaviour change the interaction with my participants needed to be simplified. Therefore, with all the learnings from my first and second design experiment, I decided to take a new turn and started developing a third experiment to answer my research questions.

## Chapter 4. Designing for individual and collective action through a technology enabler

This chapter introduces two design experiments. First, it describes the design development of Climate Pal (CP), a system that builds on a custom-built, voice-based device that is connected to a set of sensors and online, open source datasets to provide feedback to that device. CP is the result or manifestation of the investigation process in which I aimed to understand how design research can be applied to change energy behaviours and thereby reduce pollution in cities. By applying specific insights from behavioural science in practice, CP was designed, developed and tested in the context of home assistant devices to explore their potential in enabling low-pollution lifestyles in the future. Moving beyond mitigative behaviours, the third experiment is set out to develop a system that could shift the focus from pollution monitoring (measuring pollution that has already been produced) to pollution prevention (pre-empting pollution before it is produced).

Second, this chapter introduces the development of the final design experiment of this Ph.D. that aims to enable collective action by connecting a small group of participants through their AI home assistant devices to reduce their environmental impact.

### 4.1. Developing a new, custom-built device, Climate Pal

In the third experiment, a new device known as Climate Pal (CP) was developed to answer the first research question and enable preventative behaviours through design for behaviour change, and test whether polluting and energy-intensive behaviours could be pre-empted before participants perform them:

(1) Could a connected technology be designed to engender preventative behaviours and afford a more proactive role for citizens in making and/or supporting the decisions that prevent pollution in cities? (bottom-up, individual change)

Unlike current smart home devices which automate behaviours – such as Nest and Tado, which for example, switch the heating on or off at a given time – Climate Pal was designed to remind participants to take action or make decisions themselves. If a participant was about to leave her/his house with the lights or heating on, for instance, the device would ask her/him to go back and switch it off. The experiment builds on the ‘ritual’ of Steven’s initial text reminders to me (detailed in Chapter 2. Section 2.3); it tests the hypothesis that if participants are reminded to perform certain behaviours repeatedly, those behaviours will develop into persistent habits that continue even after the device has been removed from the household.

The experiment tests this approach by introducing a ‘storyteller’, a digital social companion that reminds people to proactively shift their current behaviours to new ones while also provides information on “the wider contexts of their own actions” (Lockton, 2015; van der Linden).

#### 4.1.1 The design method

CP is intended to provide a new, exploratory way to reduce individual energy consumption in the home. It tests the following design method:

*Table 1. What is already possible with current technological limitation of a home assistant device:*

- (1) A voice user interface or device that delivers and builds on specific behavioural insights
- (2) A device that is connected to the Internet
- (3) A set of behaviours that participants want to address (similarly to a personal carbon allowance/bank)
- (4) A set of stories that give context to those behaviours
- (5) A set of connected sensors – that provides a feedback loop between the participants and the system – are put in place:
  - a) to send data on participants’ current behaviours to the storytelling device in the home, which data then triggers the device to tell the right stories/give the right advice at the right time (participants can choose what kind of stories/reminders and character they want to match to a given behaviour);
  - b) to create a baseline how current behaviours are performed;
  - c) to measure the impact of the intervention and the degree to which it has an effect on participants’ behaviour (if any); and

- d) provide feedback to the participants on their performance by changing the stories accordingly;
- (6) An online platform that allows participants to intervene in the system, customise the rules (e.g. tone of messages, high-level persona of AI, frequency of messages, type of stories and reminders) and the topics they want the stories to cover (e.g. food waste management, cycling, air pollution, plastic, water use, etc.), and lets participants even write their own stories to themselves or to others;
- (7) A closed system in which data is owned by and only serve the interaction between participants and their own devices (privacy and ethical data management), they can also use the gathered data to observe and reflect on their own behaviours;

[As technology improves, two important aspects could be added to achieve a better outcome]

- (8) A conversational AI – to generate dynamic content
- (9) A network of interconnected devices to test and explore the social aspect of this intervention

In summary of these points and how they are applied in practice, a set of sensors provides a feedback loop (5) between CP, participants and the environment. The sensors infer participants' behaviours in the home (5.a) by measuring motion, moisture, and temperature in real time. When a certain behaviour is detected (such as leaving the home while the heating is on or taking a shower longer than five minutes) a story is triggered in CP (4) that gives the behaviour context, describing its wider social and environmental implications. The information provided by the sensors is complemented by open data sets provided online, which also act as a trigger for certain stories (e.g. real-time air pollution data in their city, energy grid status). If a motion sensor detects that a participant is about to leave the home, for example, and the air quality that day is poor – CP suggests that he/she commutes to work by cycling, walking or using public transit instead of driving. The system then evaluates whether the participants behaviours have changed (6.b) and provides real-time feedback, either through praise or additional context (5.c) – referring back to Darling's (2016) research on praise and companionship and how they can be good tools to motivate people.

The CP system is closed, and participants own their data (7). Through an online platform (6) participants can customise the behaviours they are willing to change, the stories they want to listen to (e.g. food waste, air pollution, plastic, etc.). They can also write their own stories and

reminders, which can be also downloaded by other participants (e.g. family members, friends, colleagues).

The development of CP started in November 2017. I worked with a two member-team: myself and a creative technologist, Tim Brooke.

#### 4.1.2 Participant recruitment and impact assessment

It seemed crucial that CP satisfies two criteria: first, it would need to provide feedback on any change that occurs. Developing an impact-driven model is a crucial step that most air quality sensing applications currently do not provide; second, the design method would need to involve a more participatory process that gives people the opportunity to decide what they value, what they prioritise in their daily lives, what activities and behaviours they would be willing to change, and what are the triggers that might help them change those behaviours.

Participants were recruited through a mass email distributed in my college dormitory by the administration office. I received interest from over forty-five families - but due to the high cost of the sensing equipment, I was only able to roll out the experiment in two households.

However, looking through the insights from my discussions with energy experts, Professor Sarah Darby and Geoffrey Stevens together, my participants and I narrowed down the focus of prospective stories relating the following, underlying behaviours for the impact assessment framework to work. This included:

*Table 2. Chapter 4. – Three different actions to reduce energy use in the home*

1.	<b>Reduce heating when it goes above 21°C. Every 1°C of reduction equals 10 % energy / CO2 emissions saved.</b>
2.	<b>Switch off the heating and lights when you leave home.</b>
3.	<b>Shower less than 5 minutes, as heating water uses loads of energy.</b>

Each of these behaviours required a sensor each to be able to establish a baseline. In contrast to the current vendor-led narratives around smart homes – which claim to change energy

behaviours by automation and control through a few set parameters only (discussed in Chapter 2. Section 2.2; Hargreaves et al., 2018, p.127) – my ‘baselining process’ became a critique in itself.

First, I had to find a sensor-set that had an open API. An open API was necessary to be able to access the real-time data that measured the current and future behaviours of the participants, and also for the interaction and feedback loop to work within the system. Each home had a set of sensors connected to the Internet and to each other. Each behaviour was translated into a ‘sensor recipe’:

*Table 3. Chapter 4. – The different set of sensors that needed to be provided for a specific behaviour*

1.	2 ambient temperature sensors (Reduce heating when it goes above 21°C.)
2.	1 door sensor (Switch off the heating and lights when you leave home.)
3.	1 humidity sensor (Shower less than 5 minutes, as heating water uses loads of energy.)

To be able to develop an impact assessment process, first the system needed to understand how participants had been performing the behaviours we agreed to observe and change before the experiment started. Each behaviour required setting up a separate set of sensors (detailed in Table 3.). To create a baseline and measure three behaviours alone (detailed in Table 2.), their flats needed to be filled with an array of sensors.





Figure 48. Ambient temperature sensors throughout the flat – on radiators and placed on the walls on 1.2 meters, for the most accurate results (product: Wireless Sensor Tags Canada)



Figure 49. Humidity sensor in the bathroom (product: Wireless Sensor Tags Canada)



Figure 50. Magnetic door sensors (product: *Wireless Sensor Tags Canada*)<sup>32</sup>

The system included a humidity sensor in the bathroom, to measure participants' hot water consumption; and ambient temperature sensors located near radiators and on the walls, to observe how they used the heating in their homes. An additional door sensor was set up to know when they're leaving or entering the house, so Climate Pal could say 'goodbye' or 'hello' and remind them to perform specific actions, such as 'Hi there, good morning! What a sunny day! I see you're leaving to work. Do you mind going back and switch off the heating in the living room? It's going full blast. Thank you so much! Have a lovely day and see you tonight!'. (You can listen to CP [here](#))

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<sup>32</sup>Wireless Sensor Tags, Canada. Available at: <https://store.wirelesstag.net/collections/all>

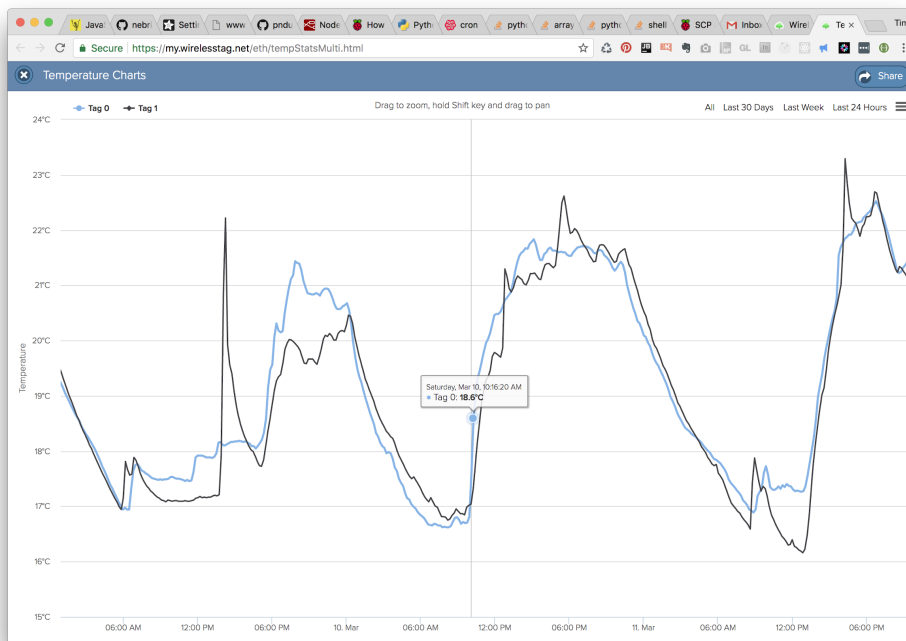


Figure 51. Testing the sensors and observing ambient temperature changes in my own flat.

Also, to be able to apply some of the reviewed behavioural insights in practice – for example, how praise can be a good tool to motivate people to change their behaviour (Darling, 2016) or that people act in ways that make them feel better about themselves (Dolan et al., 2009) – it was important that these sensors provide real-time feedback to the participants and close the interaction loop. Ideally, when the participants start changing specific behaviours, the sensors measure these changes, which then further affect CP. CP then gives feedback on the participants’ performance and changes the stories accordingly.

### 4.1.3 The storyteller and the stories



*Figure 52. Raspberry Pi and speaker*

For recording the stories, I used Amazon Polly again, a text-to-speech program. The stories generated in Amazon Polly were downloadable and got uploaded to the Raspberry Pis. First, I decided to record with a voice called Justin. Later on, however, I sent the participants a sample of recording for each available voice on Amazon, so they were able to choose the one they wanted to work with.

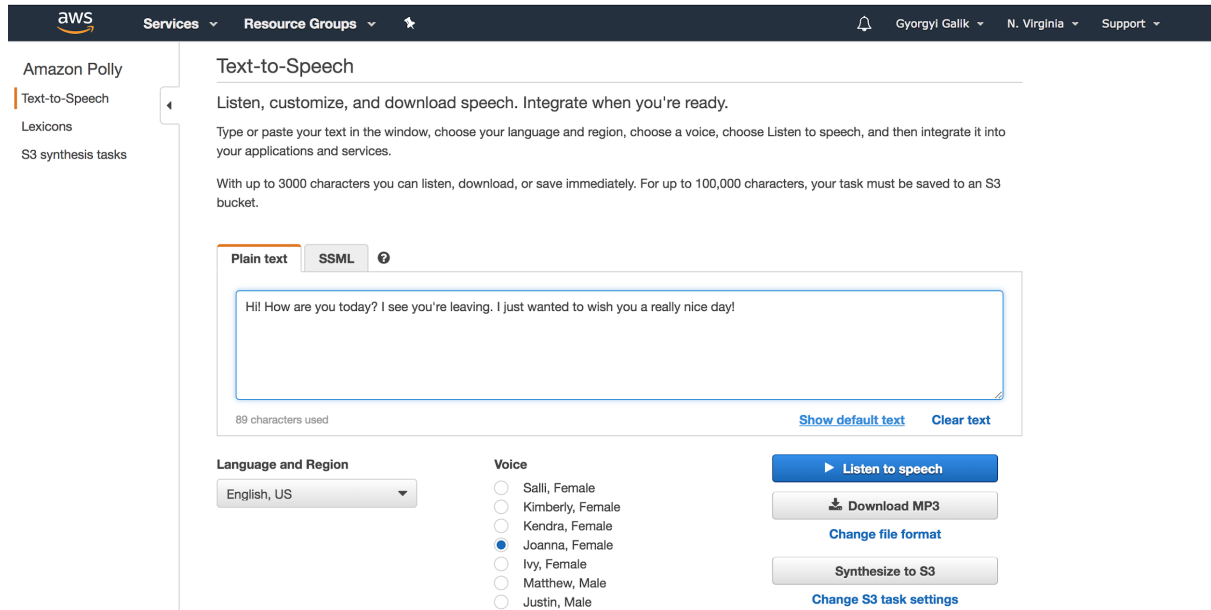
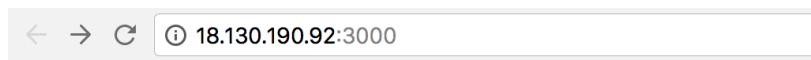


Figure 53. Amazon Polly: text-to-speech program<sup>33</sup>

A website was also developed (please find on link: <http://18.130.190.92:3000/command>) which contained all the core functions to control the fleet of Raspberry Pis home by home, the sound files uploaded on the Pis, and the triggers (the real-time data from the set of sensors: window, door, humidity, temperature) that switched on the sound files.



## Index

v 1.02

zeit

- [Command Page](#)
- [Sensor Page](#)
- [Stations Page](#)
- [Triggers Page](#)

Figure 54. Starting page of the open platform

<sup>33</sup>Amazon Polly. Available at: <https://aws.amazon.com/polly/>

# Commands

Station 01   
door\_01   
PlaySound

# Commands

✓ Station 01  
Station 02  
Station 03

# Commands

Station 01   
✓ door\_01  
door\_02  
door\_03  
door\_04  
door\_05  
door\_06  
door\_07  
door\_08

Figure 55. The Commands page where the different homes were labelled Station 1, 2, 3. The different sound files that started playing whenever the door opened

On the Commands page the different homes were labelled Station 1, 2, 3, depending on the number of participating homes. Door\_01 was one of the sound files which got triggered when someone left their home in the morning. Each sound file was given a specific time limit. The morning messages were only played until noon, to ensure that morning messages were not played in the afternoon or in the evening. PlaySound was a button that could be used for testing / playing each sound files in the drop-down menu.

## Triggers

```
{
  "triggers": [
    {
      "startTime": null,
      "endTime": null,
      "sensorName": "Reed Sensor 3",
      "command": "say_door_phrase",
      "action": "open",
      "id": 0,
      "stationId": "station03"
    },
    {
      "startTime": 819185400000,
      "endTime": 819219600000,
      "sensorName": "reed",
      "command": "say_door_phrase",
      "action": "open",
      "id": 1,
      "stationId": "station03"
    }
  ],
}
```

## Stations

```
station02 2018-08-15T16:56:43.543Z 959
station01 2018-08-14T17:35:01.191Z 84103311
```

## Commands

Page visits: 389

## Log

```
[
  {
    "name": "Nicolas_Door",
    "uuid": "0ee57dd7-bd65-46bf-aldc-6aldbae36bb4",
    "action": "close",
    "timestamp": 1534239329932
  },
  {
    "name": "Victoria_And_Ben_Door",
    "uuid": "03547463-0e79-4724-bd1c-2e5ef39babf4",
    "action": "close",
    "timestamp": 1534242735603
  },
  {
    "name": "Victoria_And_Ben_Door",
    "uuid": "03547463-0e79-4724-bd1c-2e5ef39babf4",
    "action": "open",
    "timestamp": 1534242903743
  },
]
```

Figure 56. The platform contained a 1) Command Page, a 2) Sensor Page, a 3) Stations Page and a 4) Triggers Page

'Triggers' were the door, humidity and temperature sensors that sent real-time data to the Raspberry Pi when the heating was too much, someone showered too long or left the house for



the day. Through the ‘Stations’ page we could see that the whole fleet was still online and working properly. The ‘Commands’ page was logging the actions of the different sensors and sent the commands to the Raspberry Pi.

With the complexity of the open API sensor-kit, Raspberry Pis and speakers altogether, from the forty-five participants that I originally managed to recruit, I was only able to roll out the experiment in two families’ home. The original plan was to measure showering, heating and commuting behaviours through this method.



*Figure 57. The final device: humidity, door and ambient temperature sensors, Raspberry Pi (in a protective case) and a speaker*

For example, one of the participants starts showering in the morning the moisture peaks in the bathroom. If the peak is higher more than 5 minutes, CP starts talking about water scarcity and e.g. how we use so much energy to heat up water for people’s homes. It gives context to them why reducing their shower time would be beneficial to water scarcity in London. When the heating goes above 21°C CP encourages people to reduce the heating by 1°C and put on a jumper. When they leave the house to work it wishes them a good day and tells them about air quality data and how they could consider walking or cycling instead of taking their car. With participants’ consent, a baseline data was collected to see their behaviours before the

intervention.



Figure 58. A scenario for reducing hot water use and showering time. Illustration © Niklas Hagemann

The most impactful behaviour change would have been to reduce heating in the homes. With time limitations and unexpected technical challenges, I ran out of the heating season and only managed to develop the connection between the door sensors and the Raspberry Pis. Therefore, I wasn't able to measure the impact of the intervention through the humidity and temperature sensors, even if I had the baseline data of participants' heating and showering habits.

#### 4.1.4 The conflict between impact assessment and sustained user engagement

Measuring participants behaviours through a set of sensors created yet another tension. In his critique of the approach of HCI and persuasive technology interventions, Brynjarsdóttir et al. (2012) points out that the “emphasis on sensing users' behaviour means that [persuasive] technologies limit their focus to aspects of sustainability that are clearly measurable, such as the amount of electricity that a person uses” (p.951). They go on to argue that this leaves out many definitions of sustainability that HCI could address (ibid.). In short, HCI and persuasive technologies often frame human behaviour with respect to metrics that can be quantified, and by



doing that, these technologies limit their focus to aspects of sustainability that are clearly measurable (ibid.).

During the third experiment I soon enough realised that addressing only those three behaviours (detailed previously in Table 2.) that were quantifiable through the set of sensors, and the stories that could be formed around those behaviours, were limited. My participants' feedback made it clear that the repetition of the same stories quickly became boring. As Nicolas referred to it once, "we wanted to hear more interesting facts...even more facts, so it doesn't become boring".

To sustain the engagement of my participants, I decided not to limit the stories to heating and water use only but open up the questions to wider issues of sustainability. Through encouraging small actions that an individual could take, the stories varied from food waste collection, air pollution and sustainable transport, in addition to electricity use and heating in the home setting. This also addressed the crucial point of Brynjarsdóttir et al. (2012) encouraging practitioners not to frame sustainability only through quantifiable things.

Improving the user experience with CP and my aim to assess the impact of the intervention were in conflict. Through current metrics of sustainability and sensing technologies, I wasn't able to observe the direct correlations between my participants' behaviours in the home and the stories that might have enabled the biggest impact. This raised a number of questions on impact assessment and around new metrics or approaches that could be developed to understand social and environmental value, and the framing of sustainability itself, which all can be explored and tested in future iterations of the project.

#### 4.1.5 Outcomes and insights from the third design experiment

Whilst the sample size and the duration of this experiment were limited to make significant claims about long-term behaviour change, this experiment still offered evidence for changing domestic behaviours through the deployment of a connected system in the home setting.

The day-to-day (sometimes hourly), 'neighbourly' interaction and conversations with the two participating families, the testing and iteration of the device and the system in place allowed me to gain invaluable insights into human behaviour and motivation, and reflect on the assumptions that are made by current smart home devices in relation to those. The proximity to my participants and the detailed, qualitative aspect of the data gathered about their subjective

experience were the only ways I could iterate and fine-tune the user experience with CP. In this way, the device actually responded to participants' needs in a more nuanced way and, in return, they sustained engagement with CP. The insights my participants shared with me were also crucial in developing the next iteration of the experiment.

Overall, after the four-week long experiment, the feedback from my participants was overwhelmingly positive. As the dad, Nicolas from the Chilean family described:

“In general, we were quite excited about having Climate Pal in our home. And every day it was kind of a surprise to hear new stories...although sometimes there were some repetitions, but there was an excitement from us to interact with her. Although we had it for only a few weeks, the interaction with it was regular and daily. We had expectations of hearing it and waiting for it to talk when we opened the door. It wasn't only the technological novelty for me, but it felt as if it was taking care of us. And even after a few weeks she became part of our family.”

#### 4.1.5.1 Growing emotional connection

Victoria, from the young couple, described enjoying the CP's presence in their households – even without the conversational element. Even if I had been able to provide a conversational AI element in this phase of the technology development, with current technological limitations of AI assistants, the user experience would still not have been satisfying. For those of us who tried to have a meaningful conversation with our home assistant devices this probably doesn't come as a surprise. While the technology has hugely improved in recent years, current AI assistant devices still have a long way to go before being able to conduct a real and enjoyable conversation. Moreover, the question remains how far these technologies can be developed and whether they will ever be able to conduct in depth and meaningful conversations about complex social and environmental matters.

In spite of having these questions in mind, it still came as a surprise to me that even with a simple system like CP, within the first few weeks of the intervention, participants developed an emotional connection. As Victoria described:

“First of all, I just loved when she would talk. So, I would open the door and sometimes I would remember that she might talk, and I would sort of wait and see if she is saying anything and I was always happy when she did.”

And as Nicolas noted about their experience living with CP:

“We missed it when it was gone. When we opened the door, my kids were waiting for her to talk. But it was not there anymore. Although they still remember the stories, she told us. So they kept reminding me to follow the advices she gave...while we had her, it felt as if it was looking after us, that it was benefiting us in some way.”

This raised further ethical questions that I hadn't fully considered prior to the research. I didn't expect how attached the participants would become to their digital companion and what it would mean to them when the device was removed from their homes. People's emotional response to research experiments is something that needs to be carefully considered in future iterations of the experiment.

Spending only a week with CP, participants started referring to the device as “our little friend” or felt bad when they left home, while the device was still talking: “once I was in such a hurry that I shut the door on her as I was leaving, and I heard her talking to me while I was walking down the hallway.”

#### 4.1.5.2 Learning about and breaking down sustainability into small actions

Listening to the device's stories every morning when they left the house both families said they learned about a variety of issues, some which they hadn't considered before, such as water scarcity, meat consumption, or food waste collection. As Nicolas noted:

“I think of us as a family with fairly sustainable lifestyles. We always walk everywhere for example. But it made me consider more on how we use single use plastic for example and waste management in the UK. Our little friend, I mean CP made us aware of this issue more.”

#### 4.1.5.3 Co-designing the stories

In collaboration with the participants, I iterated the length and timing of the different audio files during the experiment to ensure the device didn't become too annoying. I also encouraged the

participants to write some of their own trigger narratives and reminders that was then uploaded to their device. From their feedback during the process, I learned that the stories needed to be shorter, so they could listen to them fully. Long stories were too hard for participants to focus on, especially during the morning rush. As Victoria described:

“Once I was in such a hurry that I shut the door on her as I was leaving, and I heard her talking to me while I was walking down the hallway. That was the only time I missed her. But these things didn’t bother me. I didn’t think she was annoying, or she talked too much. I really enjoyed having her and I would definitely have something like this in my house.”

After testing a few iterations and changing the rules of the system to address my participants’ feedback, we settled on the right length of and their interest areas for the stories. As Nicolas explained:

“In the beginning some messages were a bit too long when we were in a rush in the morning, but that was an improvement when they got shorter.”

#### 4.1.5.4 Infrastructural barriers to change

While the motivation to perform the new behaviours were there with both families, some of the behaviours such as collecting food waste the participants didn’t have the opportunity or the necessary infrastructure in place to perform the uptake of the new behaviour. As Nicolas explained about his experience:

“The challenge was when I wanted to start gathering food waste, for example, I realised there is no system set for me to properly do that. Someone needs to set these services in place for us first, so we can actually do them. Some other actions were in our power to do.”

This result supports the same argument of those before me (Lockton et al., 2014a, 2014b, 2014c, 2015; Marteau et al., 2014; Brynjarsdóttir et al., 2012; Shove, 2009; Ockwell et al., 2009;) that without the necessary institutional, structural and infrastructural changes in place individuals will not be able to alter some of their behaviours to reduce air pollution and mitigate the effects of climate change.

In the case of Victoria, CP made her especially conscious about her consumption of disposable plastics, such as carrier bags and water bottles.

“This is something I thought a lot more since we had her. She would talk every time when I was about to leave home, it gave me an idea on how I could improve my own consumption and reduce my own plastic use. I really loved having it. It was nice to have that reminder before you run out of the house for the day.”

Interestingly, this effect wasn't always directly related to the content of the stories. It was surprising to see the connections she made between the different stories and how those made her think about her daily activities, sometimes completely indirect ways. For example, on a morning when CP told her about the impact of cattle on greenhouse gases emissions – she remembered to bring her reusable water bottle to school, to avoid buying a disposable one. She said she remembered to do this not because of the message about cattle, but because hearing CP's voice reminded her of a previous day's message informing her about the harm of disposable plastics.

#### 4.1.5.5 Unexpected outcomes

There were also five quite unexpected outcomes with both families: first, listening to the interviews afterwards, both families remembered advice that CP gave them that wasn't actually included in its programme of stories. It seemed as if the device started to encourage sustainable behaviours outside of the scope of the experiment.



Figure 59. A sketch capturing a dinner discussion between Nicolas and his in-laws visiting from Chile. Illustration © Niklas Hagemann

Second, during this design research experiment, technical glitches became a source of novelty and led me to key insights that I hadn't even thought of. One day, while the in-laws of Nicolas were visiting them from Chile, during the family dinner someone opened the door, which triggered CP to tell a story outside of its set hours. While they were eating some beef pie, the door triggered CP who, by complete coincidence, started talking about the importance of shifting towards a plant-based diet and encouraging them to eat less red meat.

As Glanville (2009) argues while explaining the exciting similarities and differences between design and conversation:

“in most models of communication, the concern is to reduce error, in design the so-called “error” may be a source of novelty. What is often thought of as error is welcomed as a means of enhancing creativity. This novelty comes from everything in the system working together.”

Third, after listening to stories, both families described how they had conversations about the facts and actions. In the case of Nicolas, as mentioned in the previous section, his in-laws became part of the experiment (see interview in Appendix 10). Having listened to the stories together, they then discussed them as a family during dinner time.

Victoria and Ben described having their friends over for drinks or dinner and how they would also discuss and debate the topics and stories that CP shared with them:

“My friends thought it was really interesting. When people were in the living room and she would talk. People were startling at first, but then everyone would be quiet and listened to everything she said. Which was nice because it caused a little bit of a ‘pause’ I guess.”

Fourth, in a follow-up interview, Nicolas also described how his son started reminding him about things that CP had told them about, but that he had already forgotten. For example, his son asked him to carry grocery bags with them to the supermarket and travel to school by bicycle or scooter, even on the days when the air quality was good.



Figure 60. Participants started reminding each other to the stories and advice that CP shared with them. Illustration © Niklas Hagemann

Unexpectedly, the experiment evolved into design for family and/or household behaviour change. During our conversations Nicolas also described how CP’s reminders to observe and proactively participate in these small, daily exercises made him feel they were building a more positive future together for the long-term. The device enabled collective, cross-generational

action at a family-scale and had a greater collective impact than if it had focused on an individual:

“My son reminded me during the day what she had said the morning before. My son has a better memory for these things than I do...This device tried to help us improving our quality of life, making things better every day to have a better future for my children.”

This outcome brought me back to Van der Linden’s research (2018, p.211) that it is key to inform people about the behaviour of important others and raise normative expectations about what type of behaviour is “typical and desired”. The more people follow a behaviour, the stronger the “social signal becomes”– persuading others to further comply. The more people hear their friends, family and social circles talking about environmental issues, the more these issues will be viewed as risks that require further action (Van der Linden et al., 2015, p.759).

The fifth and perhaps most delightful outcome with both families was that after CP was removed from their homes, they kept hearing her voice and advice as they were walking out the front door in the morning. This outcome was an effect reminiscent of Pavlov’s (Pavlov, 1927; McLeod, 2018) classical conditioning studies, in which dogs learned to associate a metronome with food and developed a new behaviour. My participants described how after CP was removed from their homes they continued to think about her voice and advice as they were walking out the front door in the morning. Both families reported that the feeling of anticipation that she would talk prompted them to change their behaviour, going back in the flat to grab a reusable grocery bag or switch off the lights. As Victoria described this feeling of anticipation in our follow-up conversation:

“A few months after the experiment I was about to open the door that used to trigger CP, I had the thought...’wait a minute’, and I would remember to go back and bring a water bottle with me even without opening the door.”

Lastly, both families described how they had a greater sense of trust for CP than they would have for a device like Google Home or Amazon Alexa. They explained that this was because they understood how the device worked, they owned their data and knew that data wasn’t being used for commercial purposes. As Nicolas described:



“I would have felt uncomfortable having an Alexa in my home. It is so corporate and always wants something from you and Amazon profiting from it. But I trusted this device as I knew how it worked. I saw what happens with my data. I owned the data.”

#### 4.1.6 Overall limitations of the project and recommendations for future development

Our two-person development team faced a variety of technological issues during the development of the third design experiment.

##### 4.1.6.1 Improving user experience

Both families expressed a desire to have follow-up conversations with their CPs. With further development, home assistants can become better conversationalists and this challenge could be addressed. As Nicolas commented:

“When she wished us a nice day, it was kind of nice to have her. Although it would have been great if we could interact with her and wish her a nice day in return.”

Participants also requested that in further developments of CP would give them more feedback about how their behaviour was changing in the household. With positive encouragement, they believed they would be more motivated to maintain their new behaviours. This reminded me to the research of Fasola and Mataric (2012, p.2514) again, describing how praise and companionship can be good tools to motivate people to uptake and maintain new behaviours.



Figure 61. A sketch depicting how CP is connected to open datasets on the Internet to provide real-time information on air pollution, traffic congestion, weather, etc. Illustration © Niklas Hagemann

Nicolas also said he would have preferred to listen to the stories while having breakfast or brushing his teeth, rather than at the moment when he was leaving the house. This was especially true for advice that required forward planning, such as choosing a different outfit or leaving the house earlier. This made me realise that I don't only need to develop and provide the right advice at the right location, but also at the right time, as a series of behaviour changes are built on each other and need to happen before that one behaviour can be changed. The experiment suggests that a trigger device can indeed support these changes by intervening or disrupting people's day-to-day behaviours with the right advice, provided at the right time and at the right place. If necessary, at multiple occasions. Through real-time data that a more advanced technology system could gather and provide in the home – while also being connected to online data sources (e.g. carbon intensity of an electricity system, air pollution, weather, etc.), the advice, its timing, frequency and place could be changing flexibly, and reflect and evolve according to people's real-time behaviours and needs to support a low-pollution transition.

Due to continual advancements in technology, this moment of disruption or this 'right advice at the right time and right place' approach can now be delivered to people. And while the value-action gap is described as a conceptual gap or a psychological phenomenon, this line of thinking

raises the question: could technology enablers be designed to bring a missing feedback to the gap between value and action where no feedback was going before? Could this new approach support demand-side response strategies, enable the reduction of energy use, and bring energy production/generation and the interrelationship of energy supply and demand closer to everyday people and help them understand their own and others' impact on the environment?

This thinking is similar to how Donella Meadows (1999, p.13) describes the “missing feedback” in her 6<sup>th</sup> leverage point that “[it] is not a parameter adjustment, not a strengthening or weakening of an existing loop. It’s a new loop, delivering feedback to a place where it wasn’t going before.” Missing feedback is “one of the most common causes of system malfunction” and she argues that “adding or restoring information can be a powerful intervention” (ibid.). However, she also emphasises that it’s important that the missing feedback be restored to the right place and in compelling form explaining this through the example that “it’s not enough to inform all the users of an aquifer that the groundwater level is dropping as that could initiate a race to the bottom” (ibid.).

The third design experiment can serve as a useful basis in the design development of similar approaches to behaviour change and how new technologies could be designed to understand the potential opportunities that lie in the established findings.

## 4.2 Final design experiment – Enabling collective action through a network of AI home assistant devices

To answer my second research question, a fourth design experiment was developed:

(2) If networked, could a novel interaction be designed to stimulate societal demand for environmental regulation (top-down, systems change) and to aggregate the small impact of individuals to achieve a greater collective impact?

The final experiment aimed at connecting a group of people together to enable collective action through a network of AI devices in their home that are connected to the Internet and to each other. To be able to answer the second research question, a set of home assistant devices needed to be connected together allowing a group of like-minded participants who owned such devices to collaborate with each other. The aim was to test whether and how the small impact or

behaviour changes of individuals could be linked up and achieve a greater, collective impact if they worked as a team.

As the custom-built CP system developed in the third design experiment was not ready to be scaled up and to be tested with multiple participants, and neither was the technology developed to a stage that the devices could be connected to each other, the final experiment was built on existing Alexa-enabled Amazon Echo devices in participants' homes that are already in a network.

#### 4.2.1 Applying behavioural insights from the literature review

This idea was borne out of the literature review in Chapter 2 which, by providing a better understanding of the psychology of everyday people's relationship with and perception of complex social and environmental matters, such as air pollution and climate change, has identified the main barriers to individual action. The most critical ones are perceived and actual governmental inaction and people's belief that they do not need to act, as others do not act either (Ockwell et al., 2009, p.310).

While helping participants better understand how to challenge government inaction through advocacy and stimulating demand for policy change, the aim was to test how new technology enablers might enhance people's agency in taking meaningful action as a collective; through developing a sense of collective agency and by aggregating their individual actions at a scale, to help them overcome the perception that individual actions do not matter and are somewhat futile when it comes to the inaction of a whole world of other people.

As there are millions of AI assistant devices have been sold worldwide, could they be used to enable collective action? And would the social aspect of the intervention would make their engagement and the changes in their behaviour more durable than if the intervention were to have stayed solely focused on individual action.

The experiment was built on the learnings from behaviour science and social psychology, detailed in Chapter 2. Social psychology research suggests that it is hard for people to understand climate change if their lives haven't been directly affected by it. Van der Linden et al. (2015, p.759) suggest that "public policymakers will need to appeal to both people's analytical and experiential processing systems" and describe the impacts of climate change through personal

and local experiences, engaging narratives and metaphors (ibid.): “climate change risks need to be translated into relatable and concrete personal experiences”.

Van der Linden et al. (2015, p.761) also explains that people’s daily worries override plans for the future. Therefore, replacing current narratives about a future and (both spatial and temporal) distant threats with the present, local challenges that are already happening in people’s immediate communities, might be more effective in sustaining engagement.

Nesse and Baechler (2011, p.1) note that the “translation of abstract data into meaningful information for people to use, and tools to help them make a positive impact” might have a more enduring effect. These insights helped guide the development of this experiment.

#### 4.2.2 Combining the design research methods of the first experiments

For these insights to be applied in practice, the experiment returned to design research methods that were tested in the first and second design experiments of this PhD, and it also brought back the principle of piggybacking on an existing network of Alexa devices in people’s homes. As I already owned an Alexa device prior to this PhD, the experiments were built on this device, however, they could have been run on any other platforms including Google Home, Cortana, Facebook Portal, etc.

As Amazon Alexa and other home assistant devices on the market at the moment are not yet developed with features that the experiment required, the interaction was built from scratch. The only function that allowed the experiment to be run is Amazon’s recently released ‘drop-in’ feature, supported only on Alexa-enabled devices, that lets users connect instantly to others. This feature works like a walkie-talkie between two or more homes that allow users to connect to each other through their own devices.

With current limitations of conversational AI assistants and to test whether such a new, socially and environmentally minded skill for these devices could be developed, I decided to act as an Alexa myself – reapplying the design method of the second experiment of this PhD. Again, I used Amazon Polly’s ‘text to speech’ function and recruited a group of participants who already owned an Alexa device and who also allowed me to use such an intimate function in their personal space. An expert UX researcher helped me to set the minimum length of the experiment to ten days, to be able to gain valuable insights without being too disruptive in the participants’ day-to-day lives.

After a four-month long recruitment process, the experiment was run with four participants, Jessie, Indira, Viktor and Heiko, with a fifty-fifty percent gender balance. One participant had a family, two participants lived in a couple, and one of them was a single person. Their backgrounds varied from project management, data science, design theory and creative technology. Their ages varied from twenty-five to fifty. As the experiment was not set out to convince people about whether climate change existed or not, the recruitment process was aimed at people who had already felt the urgency prior to the intervention that something needed to be done to reduce pollution and/or to avoid catastrophic climate change.



*Figure 62. Heiko, Indira, Viktor and Jessie listening to the evening feedback from CP on how they were handling their agreed daily action*

From the very beginning of this experiment the research insights of Frey and Stutzer (2006, p.9) were applied, who explain that:

“personal relationships foster intrinsic motivation. Mutual acknowledgment of one’s obligations and responsibilities is appreciated among friends, colleagues and family members. Thus, team-based or community-based structures provide motivational benefits.”

Collective action motivates people to take action (Frey and Stutzer, 2006; van der Linden, 2018). Frey and Stutzer also explain (2006, p.10) that the more people participate in decision making, the more they will adopt decisions as their own: “the greater the possibility to codetermine, the more the citizens would adopt decisions as their own. Participation thus raises self-determination and is a precondition for reciprocity.”

#### 4.2.3 Developing the experiment with participants

To help participants develop the feeling of ownership, they were asked to design the details and terms of the intervention themselves. They were also asked to share continuous feedback through WhatsApp messages to be able to customise the intervention to their ongoing needs. They set the ideal length of the experiment to fifteen days. The intervention included an onboarding email and ‘welcome’ message explaining the ground rules and setting their expectations, a survey (see Appendix 11), ten days of interaction with participants in their home, and conversations with them during and after the experiment (summarised in Appendix 12-15). They also received a set of AI voices that they could choose from to customise the assistant to their personal preferences.

Participants also set the timings when they wanted their AI assistant to drop-in on them. They all agreed that the mornings and evenings, before and after work, were the ideal times for communication. As the drop-in function currently allows users to connect to each other’s homes without further notification – apart from a little circling greenlight and a short beep sound, an exact drop-in time had to be set to protect participants’ privacy.

They chose the topics they were most interested in learning more about. Participants also decided on the actions they wanted to trial. As one of the participants, Indira reflected on this (detailed in Appendix 15): “I liked that we could choose from the behaviours...it felt like we weren’t being told. CP was interested in the things that we also found important...”

Regarding the collective action element, instead of choosing one action by voting for the one they all favoured the most, participants asked CP to trial all four actions that were put forward, so the ideas of each team member could be equally represented in the experiment.

As participants started researching and questioning the actions themselves, some of the ideas they asked the group to act upon – and the questions they raised about what could be possibly achieved – were also new to me, which made the initial experiment more interesting than expected and demonstrated the power of participatory design.

#### 4.2.4 Interaction through a combination of communication channels

The experiment was working through two communication channels: the Alexa device itself and WhatsApp. WhatsApp was added, so that participants could listen again to messages if they missed their drop-in sessions, or if they found a message too complex. As participants did not know each other, each participant had their own WhatsApp channel with CP, and they were not directly communicating with each other. WhatsApp also helped to design trust with the assistant. Specific links to the research sources were shared in a follow-up message on WhatsApp. In this way, participants knew where the information came from and could expand their knowledge about subjects they wanted to know more about. WhatsApp also allowed them to have a minimal interaction with their AI assistant and ask follow-up questions. Two of the participants really enjoyed asking follow-up questions. If this experiment was ever productised, the evidence suggests that a platform allowing users to access messages and links anytime would be valuable. As Heiko explained (detailed in Appendix 12): “I really liked both the call at a specific time and the WhatsApp follow up, so I could relisten to the message if there was a bit of detail that I missed. I really liked that.”

While the participants were all aware that I was acting as an AI, still they were excited to immerse themselves into the world of Climate Pal. As Indira mentioned: “After a few days in the experiment, oddly, I also forgot that it was you behind the machine...”

I created a separate Gmail account for Climate Pal and I also asked the participants to add my phone number under the name of Climate Pal to their WhatsApp channel, so these little details might support them better immerse into the experience:



Hello and Welcome! \ (0\_0) /

**Climate Pal** <climatepal01@gmail.com>

to heiko.maerz ▾

Dear Heiko,

Thank you for agreeing to take part in this experiment!

Please listen to your first message from your personal AI assistant, Climate Pal (CP):

[\ \(0\\_0\) /](#)

Your questionnaire to fill in:

<https://www.surveymonkey.co.uk/r/K9QYSM7>

I'll be in touch soon,

Climate Pal (CP)

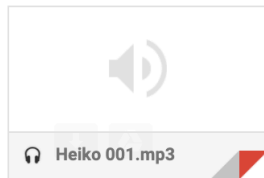


Figure 63. First 'Welcome' message to one of the participants, Heiko

The participant survey was built with the help of a user research expert to make sure the questions were set right to gain the necessary insights to customise CP to participants' needs. Jessie, for example, notes that she needed support in making more sustainable choices when buying beauty products, feminine hygiene, clothing choices, and what foods to avoid. Indira was more interested in the unintended consequences of different solutions, and the effect of being online and cloud storage on the environment. Heiko felt that he needed to change his behaviour from a morality perspective, specially living in a Western society, contributing more than average to the problem. He wanted to be more informed about holistic approaches to his actions. He was interested in the trade-offs between different decisions.

Participants' answers allowed the assistant to reflect on their interests in day-to-day interactions. Within the survey questions, participants were asked to identify what topics they were most interested in, and to describe moments when they would have appreciated some help in making an informed decision relating to sustainability and/or climate change (e.g. what vegetables to buy, sustainable packaging, waste management, transport choices, etc.). The survey asked them to list behaviours that they believed to be polluting, and the behaviours they were willing to change and the ones they were not. Participants were all willing to change their diets, food

consumption and shopping habits, and their heating and water use. For three participants, flying is the only option to visit their families abroad and the last participant works across Europe and needs to travel for work.

#### 4.2.5 Designing trust and sustain motivation

The first half of the experiment was more of an onboarding process. The assistant introduced the participating team members one by one. Each day someone else was featured. The assistant introduced them by their first name and some information on their background. The assistant then shared with all participants some research and advice on the topics the featured participant wanted to learn more about. These varied from food waste management, the future of aviation and fuel efficiency, plant-based diet, deforestation and active travel. Their ‘AI’ followed the current limitations of voice user interfaces and did not exceed them. For example, the assistant knew about the weather, as open APIs are available on weather data and that is something Alexa is already able to provide for users. So, their assistant said things like:

*“Hi there, I hope you had a wonderful day today, and perhaps managed to go out for a short walk to enjoy the sun.”*

The rest of the messages were solely built on the survey responses, the research topics and participants’ follow-up questions (see survey responses in Appendix 11). The phrasing of each message was built on learnings from the literature review, which reveals that, in parallel, both governmental and individual action will need to be taken to transition to a low-pollution society. Therefore, each message offered research on actions that individuals can take, as well as on top-down actions and policy change that governments will need to implement to address the given challenges. This part of the message was specifically set out to address the first aim of the second research question, which was to stimulate societal demand for environmental regulation.

*Morning Everyone, I hope you slept well. Today I will be featuring Heiko. Heiko grew up in Latin America and was shocked at his last visit by how the landscape has changed due to climate change. He is worried about the change that is irreversible in his lifetime, even if we radically changed our behaviour today. At the same time Heiko feels, like so many other people, that it is hypocritical to expect other people to act to a higher standard than our own, and he questions what happens when all those living in China and India will also reach the middle class, and want to live the kind of life Europeans have. He feels the western world has no moral right, or standing to challenge that. Heiko thinks each one of us can be challenged to change their behaviour, and give up on things we take for granted, rather than point the finger at others. He feels the urgency of this situation and encourages everyone to start changing their own behaviours now.*

*Figure 64. Each day, the first half of the voice message was introducing/featuring a participant and their background, and their own thoughts and challenges about taking action*

*Which aligns with the idea of what we're aiming to achieve here. To aggregate the impact of individual action. So what are the things we can do? According to drawdown.org: "Making the transition to a plant-based diet may be the most effective way an individual can stop climate change. If cattle were their own nation, they would be the world's third-largest emitter of greenhouse gases. Western diet is responsible for one-fifth of global emissions." Carrington in the Guardian also explains that: "Food production causes great damage to the environment, via greenhouse gases from livestock, deforestation and water shortages from farming, and vast ocean dead zones from agricultural pollution." Locally produced food is not always more environmentally friendly either", as it is stated on ourworldindata.org. However, food that stays fresh only for a day or two, like asparagus and berries, it's better if it is produced locally, as those are otherwise transported by plane.*

*Figure 65. The second half of the voice message was introducing the topics participants wanted to discuss with their teammates*

*You can look at the tag of where your food was produced. Eco-age.com notes that “a flexitarian diet means the average world citizen needs to eat 75% less beef, 90% less pork, and half the number of eggs, while tripling consumption of beans and pulses, and quadrupling nuts and seeds. To be fairer to developing nations, citizens in the UK and US need to cut beef by 90% and milk by 60%, while increasing beans and pulses between four and six times.” You can still eat red meat, but only once a week. If everyone acts together this can have a huge aggregated impact. However, “lobbyist groups in the US are a big barrier to change” as it’s pointed out on drawdown.org. They explain that “we will need to support environmental regulation that ends price-distorting government subsidies, such as those benefiting the U.S. livestock industry, so that the prices of animal protein more accurately reflect their true cost.” I hope this was a useful summary of what I know about plant-based diet. Have a lovely day all. Alexa, stop!*

Figure 66. The third part of the message was introducing the systems and political aspect of meaningful change

Every morning and evening, the voice message and all the links to the research sources were shared with participants in a follow-up message on WhatsApp.

Morning messages were no longer than 3 minutes and evening messages around 50 seconds long. The length of the messages was guided by the learnings and iterations of the second design experiment in Chapter 3., to ensure they were not disturbing participants’ everyday life.

All participants reflected on this as part of our conversations during and after the experiment. As Jessie described: “the length of the time of those check-ins was perfect. Any longer I imagine my thoughts would start drifting off.”

Mornings were about introducing new information and evenings were geared more towards a brief check-in, building trust and continuity with the device, and sharing some reflections on the day and group achievements. The initial number of check-ins were recommended by the expert UX researcher whom I was consulting with prior to the intervention. She suggested to start out with two check-ins a day and iterate the process according to participants’ needs.

Participants follow-up questions demonstrated the difficulty of addressing complex social and environmental matters without oversimplifying them. Relating to the given voice message-example above, one of the participants, Indira, asked the following question:

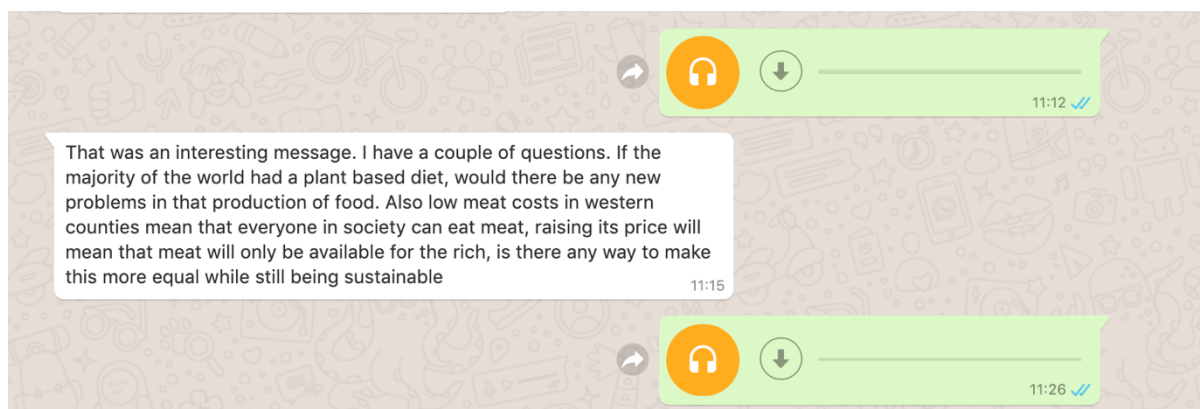


Figure 67. An exchange of WhatsApp messages with one of the participants, Indira

It took four days of research and more than 15 different articles for me to be able to answer Indira's question in a balanced way. This highlights the current technology gap and ongoing challenge to designers of AI assistant devices for how they might address or respond to complex questions while people interact with these agents.

Participants' follow-up questions were always complex and unexpected, which made me, the designer of this whole experiment, constantly reflect on my own practice, assumptions and expectations of how this experiment might turn out. It also made my own experience as part of this project more interesting than I had ever imagined. Without a two-way communication system, I would have never gained a better understanding of how participants had perceived my messages either and where they needed further help or explanation. It was a good and repeated reminder of how similar technological applications and designers of such interventions have a huge responsibility in shaping people's perception and can help demonstrate the complexity of each intervention or policy decision, and how those can also have a series of unintended consequences.

Moreover, the experiment has raised a fundamental challenge with the limitations of and points to the depth of conversations that could or could not be possible with AI agents. Understanding the trade-offs between being able to efficiently automate something – that still can have a potential impact in enabling behaviour change – and being able to facilitate a deep and informed two-way discussion that requires a human will be necessary.

In the second half of the experiment, CP asked participants to take the learnings from the

experiment and apply it through a set of real-life actions. The participants were asked to design one action each that they would act upon as a group. The outcome of their collective action was shared with them at the end of each day.

Three out of four participants were all fans of cooking and interested in changing their shopping habits, therefore, the actions they set during the trial were mainly focused on these topics:

*Last week Indira found out that the green leaves around a cabbage were edible. She would like you all to use an edible part of the food you normally throw away. And provided a link that I will share on WhatsApp. Viktor would like you to try to look up recipes before heading to the groceries and only get the ingredients and the amounts you exactly need for the recipes, not more. Cheese sandwich with cherry tomatoes is a legitimate recipe too. If you do feel safer to go out to get a bunch of groceries at the same time because of coronavirus, then try this idea in our post-COVID world. Heiko, based on his interest in plant-based food, would like you to change at least one meal per day to be completely plant-based. And Jessie asked you when you're out shopping for food, try to have no plastics in your basket. For example, if you can buy loose apples instead of pre-packaged apples, then choose these instead. Please take a note of all these 4 actions. And you can even try combining them.*

Figure 68. CP is giving instructions to the participants on the actions they wanted their team members to sign up for

After a few days all four participants started reporting back about the actions they were taking. They were acting upon the same behaviours, sometimes on different days. Indira, for example, shifted to plant-based food only, and started using some food she would normally throw away. By going plant-based, she realised how much animal produce she does use in a day, and then substituted oat milk for cow's milk.

In their reflections (detailed in Appendix 12-15) participants described that they developed an emotional connection with CP. As Jessie noted:

“The overall experience was quite exciting. It became a point that I was looking forward to it...which I know is cheesy. It was really exciting to get that little bit of injection in a fun and light-touch way. I felt really sad hearing the goodbye message...”

Heiko described how the intervention has also helped him in forming new habits:

“I have to say it was really interesting. I was disappointed when it finished...I really enjoyed the consistency of it. You know...getting something every day. Because that helps you to keep it on top of your mind. The biggest problem with these behaviour changes is that it's so easy to start with good intentions and then slipping up...the device helped me form the habit. I made the point of being with the device to hear the messages.”

They also shared some invaluable insights on how their experience could have been improved.

#### 4.2.6 Outcomes of the final experiment

Participants all managed to sustain their motivation and engagement because of a few distinct social incentives that could only be revealed by developing and iterating the final design research experiment to address the second research question: 1) the feeling of responsibility for their team to succeed and the importance of social conformity and belongingness; 2) the continuous feedback they received, which allowed them to learn from each other, observe and practise their new skills; 3) the motivation they were gaining by hearing that all of them in the group were sticking to their commitment to making it work; 4) their intrinsic concerns and curiosity about the welfare of their team members (after they started developing a connection); 5) the motivating force that they were enabling greater impact as a group than they would be able to achieve on their own, 6) the right balance of group interaction and anonymity that encouraged them to participate in the first place and 7) the element of trust, transparency and joy that derived from working with real people through the machine.

First, the feeling of responsibility for their team to succeed, of social conformity – the act of matching their behaviours to their group's actions and norms – and of belongingness – their need to be an accepted member of the group and to be a part of something greater than themselves – are proved to be equally crucial.

As Heiko described it: “doing it as a team, you don't want to be the first to slip off. There is the social element of sticking to the experiment, that makes you much more conscious of your actions.”

Jessie explained her experience similarly:

"I liked knowing that there were other people taking part. I didn't feel a specific connection to them, but if anything it made me more aware of making sure I was on top of things...it wasn't only that CP was asking me to do something, I knew there was a group out there and it would have an impact on other people. I realised other people committed their time and effort to make a difference, and I would let people down if I didn't partake. But I think that was a good thing. It wasn't a pressure...it just made me more mindful that other people are involved in this. This helped me stay motivated."

Second, the continuous feedback they received on how their team members were doing day-to-day, including where they succeeded and failed in their attempts of taking action, also proved to be a key element of participants learning from each other and building their skills. As Viktor described (detailed in Appendix 14): "I wanted to know more about how the others trialed an action and what barriers they faced, why they failed to achieve taking an action successfully. I would be less interested in collaborating with twenty people but with no details on how they were dealing with their challenges." While Indira noted:

"I really loved the links between the four of us...that you weren't on your own doing it. That link motivated me...I enjoyed hearing how they were doing, what they were up to that day, how they were dealing with our set challenges and actions in their own life."

Third, participants reported how hearing that all of them in the group were sticking to their commitment as a team was a key motivating factor. As Heiko referred to it:

"I think what would have made a big difference if other people had dropped off the experiment. As everybody stayed on...it felt that we as a group, as a collective were moving forward. Energy feeds off energy...as long as people continue to move towards a goal, it's really motivational to continue."

Depending on the group size and the overall impact on the dynamic of a group, the findings suggests that in future iterations of such a service or product will need to account for the risk of decreasing motivation and carefully design how participants opt-out.



Fourth, participants described how they kept thinking about each other during and after the experiment. As Viktor described in one of his follow-up notes:

“We are few weeks after the intervention, and I am still thinking about my teammates. How they might be doing, whether they continued the actions and what changes in their lives they manage to keep up with. Sometimes when I do something that I know it’s not sustainable...like the other day I took a plastic bag from the grocery store...and I was catching myself thinking what they would think of me...that I could not brag this if they were still around. They seemed to be too smart to just buy into substitute or fake actions instead of real ones. Also, sometimes when I feel hopeless about what to do in a situation, or which decision might be better for the environment, I am thinking they might feel the same way as I do ...”

Fifth, the sense that they were enabling greater impact as a group than they would be able to achieve on their own also sustained motivation and engagement with the intervention. Viktor described this through an idea of a future service: “in the future, with services like this one, having an assessment of our collective impact...would keep me, and the others, motivated that we’re making a difference.”

Sixth, participants were not directly talking to each other but only connected through CP. The artificial element of their pal gave them more anonymity. It seemed that interacting with an AI assistant/machine as part of the interaction, rather than with a real person, helped participants feel less ashamed when they could not perform an action. As Heiko described this in one of our conversations:

“I know myself. I will slip off eventually. And I need to steer myself back onto the right track. It is so much easier to confess that you slipped off to a machine than to a person. As a machine doesn’t judge you. If I feel that there is a chance that I get judged, I tend to interact less. To me, the machine is something that connects me to the group but also shields me from the judgement of the group. But helps steer me back to the group. For me being artificial is a positive attribute.”

This machine ‘middleman’ created a ‘boundary’ between participants and helped improve the experience of more introvert personalities in the team. As meeting their team in person was not a

compulsory element of taking action collectively, they felt less pressured joining the experiment. As Heiko noted (detailed in Appendix 12):

“I am an introvert. For me it would be really hard to meet a group of people I have never met. Eventually I think I would want to meet them, but I prefer first being onboarded in a virtual way and then meeting later in the experiment.”

Seventh, participants reflected on the element of trust, transparency and joy that derived from working with real people through the machine. They felt it was crucial that they were working with other people, even if through an AI assistant device. That they were part of a community of real people. Indira noted the following thoughts: “I wished to have continued...particularly, as it felt like a community...they were real people, not something a computer made up...”. This insight can be valuable to designers of AI assistants and other technology enablers to understand how to balance the human and community element with automation and scale.

Indira’s reflections on the elements of trust and transparency also came from the community aspect of the intervention. These aspects of sustaining motivation and engagement also need to be accounted for in the design of technology enablers. She trusted the people she collaborated with:

“I liked to get to know about topics I wasn’t interested in but the others in the team were...participants were not from a big corporation...it’s not what the company wanted me to hear, but what the other participants wanted me to learn about...it built trust instantly.”

Future iterations of the experiment could also look at the barriers, potential opportunities and emotions such as empathy and personal bond that derive from face-to-face, direct contact between participants, which this experiment was not set out to do.

Furthermore, next to the social or collective aspect of the intervention, the other key elements of the interaction that participants valued the most and helped them form a new habit were (see detailed reflections in Appendices 12-15 as well as Chapter 5. from Section 5.1.6): 1) the excitement about new learning, 2) the daily surprise or unknown aspect of the challenges that they were looking forward to trial, 3) the capacity building and the change they gained in their perspective, 4) the consistency and repetitive nature of the interaction, 5) the novelty of the

interaction with Alexa (that gave a new use for their existing device), which device then also became the symbol of their commitment to change.

#### 4.2.7 Questions and recommendations for future development

Participants shared a number of ideas about how they might use a similar service or product in the future. First, they wanted a trusted assistant that would keep reminding them to stick to their new habits and that they could also rely on with complex and nuanced calculations or decisions comparing any given choices.



*Figure 69. A sketch depicting how Jessie would use such a service: “The way I would have loved to use such a service like this, that I could just speak to Alexa and she knows my location anyway, and I could ask her to give me the most sustainable meal that I can make. With, let’s say, the broccoli in my fridge...she can have all the data in the background, what would that look like in my local area, where I am in the world, she can go that step further...she can actually start advising me on specifics in relation to my local area and interests.” Illustration © Niklas Hagemann*

As Heiko described this need in one of his messages:

“To me, it would really help me, if this was ongoing, to keep the habit and the consciousness of always reflecting on my actions in terms of sustainability. I would use this outside of my home as well. Being able to say, from a sustainability point of view, from two decisions which one is better. A tin can of ready beans from New Zealand, or the dry beans that take 2 hours to cook on the oven...using that energy for cooking takes a long time. Which one is more carbon-intensive? These kinds of decisions and comparisons, to make a more informed decision, are extremely helpful.”

Participants also expressed different views on whether they wanted to be part of a more local or a global network of people. This depended on their life experiences and personal preferences. Viktor would have preferred to have some local people from his neighbourhood “to discuss [their] experiences about shopping.”

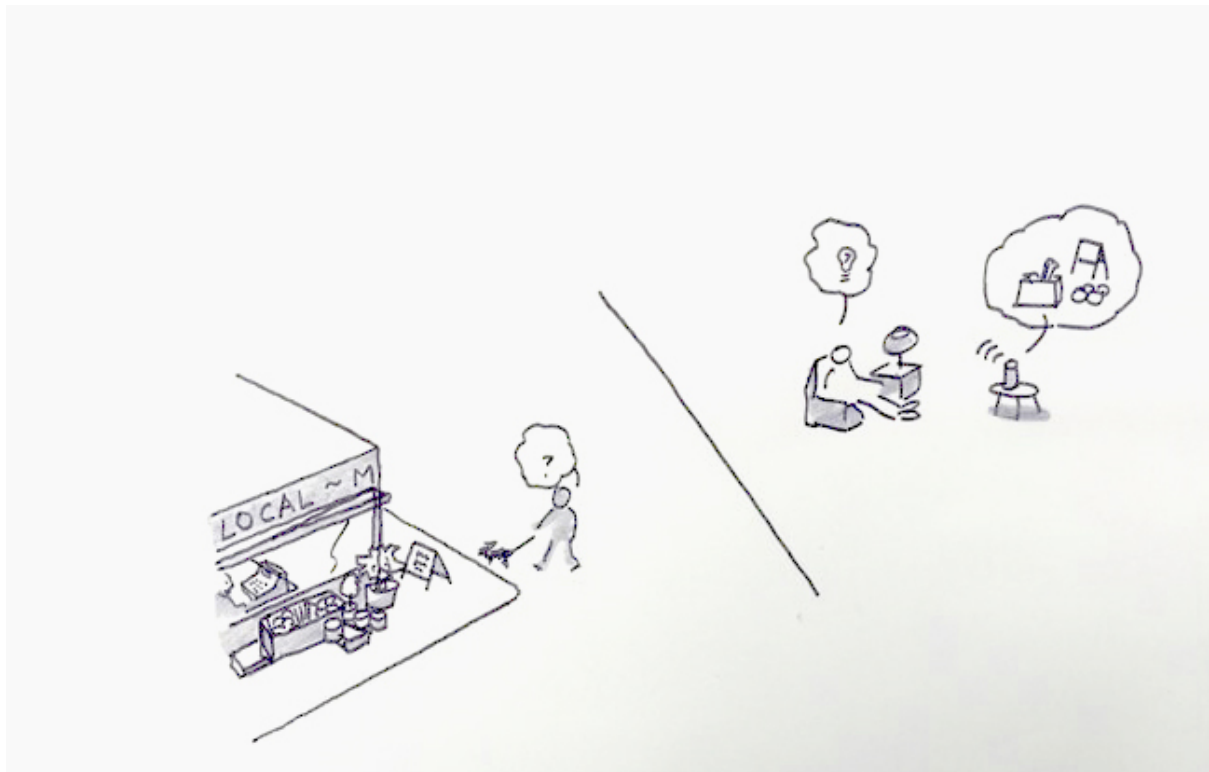


Figure 70. A sketch depicting Viktor's idea on a local network of people: “It would have been nice to have some local people on it, who live in the same neighbourhood...so to discuss our experiences about shopping. Give me more information on where I get things where I can do plastic free. That would be helpful. Or from my own circle or teammates, can they share what they've learned and how I can follow or find where they find solutions that worked successfully...” Illustration © Niklas Hagemann

While Jessie said the exact opposite:

“I think because of my upbringing, I would find it very exciting that they are from different parts of the world...different countries, perspectives, what their worlds' look like, seeing the challenges they have day-to-day...”

The key question and opportunity for the future remains the extent to which we can achieve an aggregated change through a larger set of real AI assistant devices.

With further development, a number of possible avenues can be explored, including linking stories and activities to the real-time load of an electricity grid – supporting governmental aims with demand-side response strategies, or applied in applications of local, community microgrids where generation as well as consumption (and the balance between them) comes into consideration.

## Chapter 5. Discussion

Challenging the current assumptions embedded in air quality sensing technologies, this thesis demonstrated how design research can offer new and practical ways to enable low-pollution lifestyles through a series of design experiments. This included the development of four design experiments, including a purpose-built home assistant device and an experiment that enabled collective action amongst a group of participants through a network of connected AI assistant devices.

The four design experiments set out to test how technological enablers could be designed to shift the focus from solely monitoring, visualising or observing pollution that is already out there (mitigation) to help people prevent pollution from being produced in the first place (prevention).

Current design approaches to smart applications often have a reductionist take on human behaviour. They set out to find patterns, make predictions using computer algorithms and establish statistical claims that might undermine their efforts to actually understand the nuances of what drives human behaviour and how those drivers could be utilised to help people transition to low-pollution lifestyles and become more sustainable. The capability of design research – that values subjective and complex details as ingredients to develop more rounded solutions – can help address the tension between 1) averaging, simplifying and automating any given idea or solution and 2) understanding the complexity of human behaviour and ever-changing needs of people, and how those could be better balanced in technology design.

### 5.1 The major findings of this thesis – Do not design for behaviour change but design for the change before behaviour

To enable behaviours that prevent pollution in cities, the evidence so far shows that two steps are first necessary. The first step is to provide the necessary structural, infrastructural and institutional enablers of sustainable behaviour such as investment in dedicated cycle lanes and in food waste management, which can enable faster, more positive and impactful change in individuals' behaviours (detailed through multiple examples in Chapter 1. Section 1.1.; Chapter 2. Section 2.1).

As explained in detail in the COM-B model in the literature review (in Chapter 2. Section 2.3.3 *Models, strategies and frameworks*), for any behavioural intervention to be effective and for this change to happen, *capability*, *opportunity* and *motivation* also need to be present.

West and Michie (2020) explain that the greater the opportunity and capability are the more likely a behaviour is to occur, but only when motivation is present, and the person is more motivated to enact that behaviour than any other behaviours. The authors go on to describe (ibid.):

“the more capable we are, or believe we are, in enacting a behaviour and the more conducive the environment is to enacting it, the more we tend to want to do it. When a behaviour is difficult, or we believe it to be so, we are less motivated to do it”.

If these key foundations are in place, technology interventions have a greater chance to succeed.

With similar aims to this enquiry, Lockton et al. (2014a; 2014c) explored the sonification of energy data in households, as a means to make energy more ‘visible/audible’ and encourage householders to consider their energy consumption in near real-time. Building on Lockton’s thinking around energy displays, and visual and audible feedback and also moving beyond sensory feedback of near real-time energy use in the home, I set out to shift the focus to designing a technology enabler that helps pre-empt polluting and energy-intensive behaviours before they even happen.

As a result of the first three design experiments, a new argument has started to emerge. Design for behaviour change – the field I aim to make a significant contribution towards – may focus on the wrong side of behaviour. Current projects and visualisations in the fields of design for behaviour change, HCI and persuasive technologies either focus on 1) the behaviour while it is being performed (e.g. the kettle is singing to remind people that they are using electricity to heat up the water) or 2) reporting about the behaviour that has already been performed (e.g. an energy bill detailing how much electricity and water we used last month).

The prevention-focused technology design experiments in this PhD set out to understand the third or ‘Stage -1’ side of a behaviour, the moment or space right before a behaviour occurs. With the design of the right disruption or pause – that, due to continual advancements in technology, can now be delivered by a technology enabler, the evidence established through this

PhD demonstrates that this space or moment can be taken advantage of to shift people's behaviour before they start performing an old behaviour. Subsequently, it is also argued that – while it is difficult to identify and address all the reasons for the discrepancy between people's values, intentions and actual behaviours or actions – technology enablers could help in efforts of closing the 'value-action' gap and deliver feedback to a space where it was previously missing. But this shift is only possible if the key foundations (detailed above in the beginning of this section) are in place and the 1) right advice is designed and delivered at 2) the right time with 3) the right frequency, and in 4) the right place and context.

The third design experiment can serve as a useful basis in the design development of similar approaches to behaviour change and how new technologies could be designed to understand the potential opportunities that lie in the established findings.

Instead of designing for the behaviour to change, this enquiry focused on designing for the change before a behaviour is even performed. The findings suggest that if a person wants to shift a behaviour with the help of a technology enabler or digital social companion (e.g. reducing their hot water usage, their choice of food), they also need to be supported in all the changes that lead up to that specific behaviour (e.g. to change their commute in the morning, they will need to know that way in advance, so they can find the right outfit to the specific mode of transport).

The insights drawn from the discussions I had with the participants of the four design experiments (during and after the experiments) have resulted in a set of new technology design principles (see the summary of participants' reflections in Appendixes 12-15). These design principles could serve as a valuable guide for other interaction and technology designers. The ordering of them does not reflect on their importance:

#### 5.1.1 Create a collective experience and a shared purpose with and for your participants

The third experiment evolved into design for family and/or household behaviour change through the shared experience that the intervention created. Participants described how the technology enabler encouraged them to observe and proactively participate in small, daily exercises, which made them feel they were building a more positive future together with their families through this shared experience.



The device enabled collective, cross-generational action at a family-scale and had a greater collective impact than if it had focused solely on an individual. The evidence emerged through this enquiry suggests that technologies that are deliberately designed to involve more than one person from the direct social circle of an individual – and allow them to simultaneously interact with the technology enabler – might have a more successful outcome in enabling sustained behaviour change (see interview sample Chapter 4. Section 4.1.5.5, pp.125-126).

By connecting a group of strangers through an Alexa device, the final experiment also created a shared, collective experience but beyond those in participant's direct households. Future iterations of the experiment could compare whether the impact of facilitating a collective experience within a family/household or facilitating a collective experience between different households working towards similar aims could be more powerful in sustaining motivation, engagement and change.

### 5.1.2 Transmit social incentives and set the right social signals

Behaviour is 'contagious' and setting the right examples may have the fastest impact in addressing pollution (Frank, 2020). Relating to the design of a collective experience and shared purpose, if a person is encouraged by the shared experience and actions of their immediate peers, family and friend circles it will subsequently increase the chance of their successful transition to a new habit (Goldstein et al. 2008; Van der Linden, 2018, p.207, p.209, p.211; Bicchieri and Chavez, 2010b). The more people behave in a certain way, the more rapid the uptake of that specific behaviour.

The evidence gained through the final experiment indicates that the social aspect of the intervention was the most important ingredient in sustaining participants' motivation and engagement.

### 5.1.3 Stage a deliberate 'pause' or moment of disruption

Kuijer et al. (2013) describe a "crisis of routine" in which the "breaking and shifting of structures takes place" when an "existing practice is reconfigured into novel variations that involve both new and existing elements, and new and existing links" (ibid., p.6). To achieve a positive reconfiguration of an existing practice, such "crises of routine could be deliberately staged" (ibid., p.6). The authors go on to introduce the idea of "trigger products that are new things that

can form leverage points or triggers for playing out more radically different configurations” (ibid, p.7).

The evidence established through the third experiment suggests that it is possible to design a technology enabler that intervenes at the moment right before a behaviour gets performed and gains time for a ‘pause’ between participants’ ‘auto-pilot’ behaviours and more effortful considerations of their day-to-day activities; to shift their old behaviours to new ones.

#### 5.1.4 Design possibilities for others to have conversations, to learn and to act

The third experiment created a space for others to learn about and to act on different environmental concerns (John et al., 2009; Dubberly & Pangaro, 2015, p.1). Participants proactively changed their behaviour and formed new habits which in some cases still remain. The experiment also affected people beyond the immediate circle of the participants.

#### 5.1.5 Design trust with technology enablers

In the third experiment, participants described how they had a greater sense of trust for the device than they would have for a product like Amazon Alexa. They explained that this was because they understood how the device worked, the intentions of this intervention and they owned their data (see Chapter 4. Section 4.1.5.5, p.126). The final experiment was deliberately designed to be transparent about where the sources of research were found, which helped build trust with the participants. The importance that participants placed on this transparent and participatory quality of the technology can serve as a valuable insight for other technology designers.

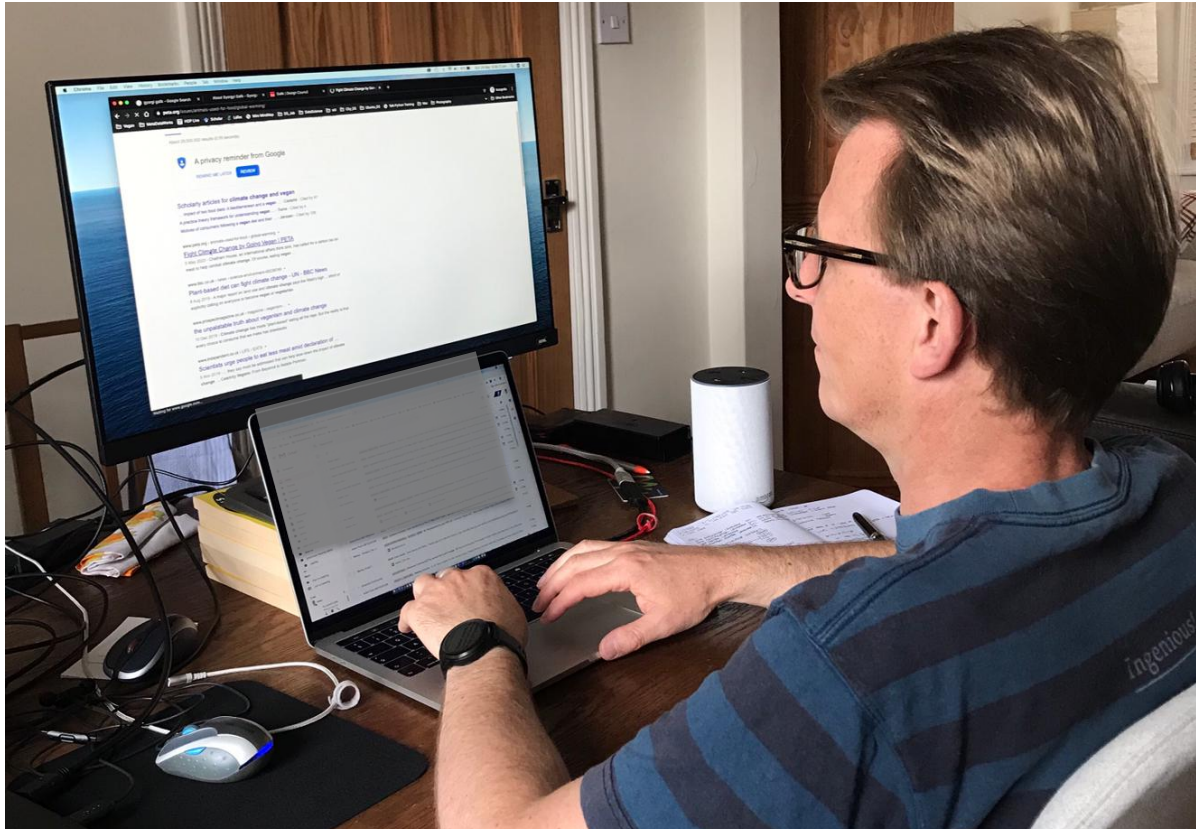


Figure 71. After listening to CP's morning message, Heiko is interested in doing some further research on some of the ideas and links that were shared. He later on noted: "I think trust is two-fold...Climate Pal made his sources transparent... You're not just telling me something, you're also giving me both the opportunity to verify and further expand my knowledge in that...if I wanted. This approach makes something trustworthy from the beginning."

### 5.1.6 Utilise the surprise or unknown aspect of a challenge that makes participants curious and motivated

Participants learned about new issues relating to sustainability from the actions that their team members asked them to act upon. Moreover, participants reported that they were more excited about and looking forward to hearing what challenges their team members might set them to achieve than their own ideas. This unknown or surprise element of the intervention sustained their motivation to participate.

### 5.1.7 Set the 'optimal challenge' that participants can look forward to overcoming

To maximise the longevity of participants' motivation with performing the actions, the new challenges they needed to overcome were integral to their enjoyment with the experience. For any behaviour to become a habit, the participants needed to keep performing that behaviour repeatedly. The goal was to encourage them to try performing an action or behaviour until they are good at it and subsequently, participants needed to be motivated by the challenge of the

actions. It was, therefore, important to better understand how the ‘optimal challenge’ (Davidson, 2020) could be set, before enjoyment began falling off.

As Davidson (2020) notes, referring to Bandura’s work on self-efficacy, our motivation to engage in any given action “comes from our own perceived ability to succeed”. Looking at gaming specifically, he explores what the right level of challenge is that makes it too hard for players to want to continue playing a game and influence whether they feel they can complete that action successfully.

- Our own knowledge of our abilities based upon previous experiences (*I’ve done this before*)
- Seeing success modeled in the actions of others (*Look how easy it is for them*)
- Social support feedback (*You can do it!*)
- Physiological and emotional feedback from attempting the act (*This is really stressing me out*)

*Figure 72. A screenshot from the article of Davidson (ibid.) detailing the four elements that form our perceived ability, NBI (National Business Innovations LLC)<sup>34</sup>*

Participants needed the feeling that they can succeed over a challenge even if it was difficult, as well as a challenge that wasn’t too easy so as they get bored with it. They also needed the infrastructure (e.g. safe cycle lanes, facilities for food waste collection) impeded that feeling, as it to be able to perform the tasks successfully.

### 5.1.8 Help someone gain a new perspective

Participants also described how the intervention helped them gain a new perspective and helped them make more informed decisions. In the case of Indira, “it made [her] link seemingly unrelated issues together.” While Heiko described:

"There were a couple of points that the others raised...that changed my perspective and the way I see things. This will stay with me. For example, what is the danger of pushing the responsibility or burden of being more sustainable to less privileged people? Indira raised that...something I have never thought of before...neither I’ve ever reflected upon. Without this experiment, I would have never thought of that.”

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<sup>34</sup>Davidson, M. (2020). Finding the optimal level of challenge: Lessons from psychology in optimising retention and engagement. NBI Analytics. Available at: <https://www.nbianalytics.com/finding-optimal-level-of-challenge/>

### 5.1.9 Provide consistency and repetition, so the body becomes trained in a new behaviour

All participants in the third and fourth experiments described how the consistency and repetitive nature of the intervention were crucial to the uptake of their new commitment and behaviours. Both families in the experiments reported that having lived with the device and repeatedly performing similar tasks had prompted them to change their behaviour.

This insight is aligned with Kuijter et al. (2013, p.5) argument that “through performance, the body becomes trained in a certain way, when knowledge about the practice becomes embodied in the practitioner”.

### 5.1.10 Provide the right advice with the right frequency and length at the right time and in the right place and context

The right time, length and frequency of the stories or check-ins were crucial to improve the overall experience of participants. After the third experiment, Nicholas explained that with certain messages they would have preferred to listen to them earlier in the morning, so, for example, “[they] could choose the right outfit when [they] needed to change to a different mode of transport” (detailed in Appendix 10). For a long-term engagement with the device, each participant preferred receiving shorter but frequent daily messages. Heiko explained how “for [him], it was very important to always have it at the same time: “again, about forming a habit. Every day I will be there at that time to listen to my message, it brings constancy to it...I made the point of being with the device to hear the messages”

Other participants also described in detail that they would have preferred to have an advance notice to get into the mindset of and set the context right for ‘listening’.

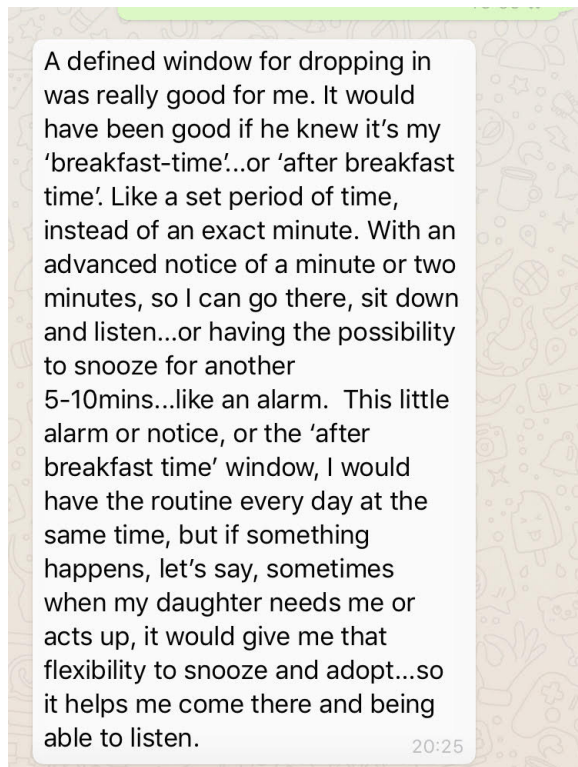


Figure 73. Viktor explaining in a WhatsApp message how the interaction could be improved to suit his needs better

#### 5.1.11 Find the source of novelty or object of commitment in the experience

In the final experiment it proved to be useful to give an old object new meaning or to introduce a new object entirely, that can become the symbol of change and commitment. Viktor noted that “when the voice messages were coming through Alexa, it felt more like a part of [his] new routine that [he] committed to”. Heiko expressed that “somehow the device became the symbol of [his] commitment and that [he has] signed up to this. It became a thing in [his] day that [he] was looking forward to receiving.”

#### 5.1.12 Set the right balance of anonymity and connection amongst group members and through the device

All participants reflected on the need for setting the right amount of anonymity in the experiment, explaining the strengths and weaknesses it results in if it is designed in an unbalanced way. Too much anonymity made them feel they could get away with doing less, as no one could actually see them. While too little anonymity exposed them too much for the possibility to be shamed in front of the group. Finding out the right balance of this will be a challenge in the design of similar technologies in the future.

### 5.1.13 Set the right group size to support emotional connection

The group size and sharing some personal information about each participant helped participants build connection with their team members. Viktor described how the right amount of intimacy and size of the group were key in his commitment and increased his curiosity:

“It was only four names mentioned...and I liked that intimacy. It was easy to think about those individuals and, with time, as I knew more and more about them, their interests, thoughts and experience, I started feeling an inherent connection to them. There is a limit of how many people I would want to work with. It would change the intimacy of the experience to me. I prefer to know about one guy in more detail and hear about his personal experience.”

### 5.1.14 Set the right amount of information that is shared about group members

Third, through the iterations of the interaction, participants reported that they wanted to know more details about each other's lives. As Jessie explained: “I would have loved to know even more about their lifestyles and about them as people.” Viktor shared similar thoughts:

“While we slowly received more and more information, knowing even a bit more would have been nice. About what kind of flat or house they are living in...especially the logistical aspects of their urban living...whether they live in family or own their own...routines. How much they stuck to their routines. Even their disposable income...”

### 5.1.15 Constantly reflect on your own role, impact and biases as a designer

As a designer of this whole process I was observing the system from within, and through the whole process – the discussions with my participants, the iterations of my experiments, the methods, tools and the system I built on and developed – I reached outcomes that I did not expect prior to this PhD and this also enabled me to reflect on some of my own assumptions and biases. In the process of designing trust, multiple participants reflected on my role “as a source or writer” of stories, within the experiment and how that positively impacted the trust and experience they had (see Appendix 11-14). They all stated that if the interaction was designed by, let's say Google, they would have wanted to know more about the process of content generation (e.g. how the stories were edited, interpreted, and where the data was gathered from). These comments also relate to the earlier discussion on trust.

Through the final two design experiments participants developed a sense of independence – and without me even encouraging them to do so – participants not only have developed a pollution- and climate-change-aware thinking as a result of the activities we did together, but after the experiments ended they also reflected on how their mindset has changed, how they continued reading and researching different topics themselves, and how they continued the ‘work’ the experiments has started. Weeks after the experiment, Heiko reflected on this in one of our conversations: “I catch myself every day since, asking ‘Oh, how sustainable was that? What would I have done differently in this situation, if I still had my daily messages?’”

## 5.2 Ethical considerations for future development

The experiments raised a number of ethical questions, which will need to be addressed in further developments of the project. Referring back to Mazé’s questions (detailed in Chapter 1. Section 1.7.3) about the role of designer and the designer’s worldview – and also to Kuchinskaya’s work on the responsibility of misleading representations of environmental matters to change public perception (discussed in Chapter 1. Section 1.5.3) – it is crucial to better understand the political dimensions and impact of the visions of our present and future of those who write the stories (Mazé, 2016, p.2). These questions have become increasingly relevant in this PhD, as I was the writer of the stories. It seems inevitable that one’s own biases and assumptions about sustainability will find their way into the stories and, subsequently, shape participants’ worldviews. It is also crucial to account for, address and increase diversity in such projects, in particular referring to data collected to develop future oriented solutions. One’s view (with its own bias and assumptions) cannot be enough to design with and for such complex matters and reflect the diversity of views, experiences and needs of people, and might even contradict somebody of a different backgrounds, gender and culture.

These all made me think of my own role as a designer and the role of other developers/creators of similar interventions, and that the governance of the content development and the question of how the stories and datasets are sourced, edited and represented to the users of such a service or product both have to be carefully designed. Furthermore, which and whose actions and discourses will be included and prioritised in addressing climate change, pollution and sustainability are all political questions. Whoever writes the stories could also potentially lead participants to an echo chamber, where their own existing beliefs and biases will be simply reinforced.



## Chapter 6. Conclusions

Moving beyond mitigative actions, which will not be enough to address the complexity and severity of air pollution and climate change alone, this thesis has explored how new technologies may facilitate articulations of citizen participation (Gabrys, 2018, p.508) as a means to afford increased agency in enabling low-pollution and low-carbon lifestyles in cities through design for behaviour change.

### 6.1 Answering the research questions

In relation to the central two research questions a set of design principles were developed through four design experiments. The first research question:

(1) Could a connected technology be designed to engender preventative behaviours and afford a more proactive role for citizens in making and/or supporting the decisions that prevent pollution in cities? (bottom-up, individual change)

The evidence that emerged through the third design experiment demonstrated that with emerging technologies it is indeed possible to intervene in the moment or space right before a person acts upon a given behaviour. As discussed in detail in Chapter 2. Section 2.1, while it is difficult to identify and address all the reasons for why the gap between a person's attitudes or values and their actual actions exists, the evidence that emerged through this PhD suggests that it is possible to close the value-action gap and enable people to shift their old behaviours to new, more socially and environmentally-minded, ones, so they can act more in alignment with their environmental values.

Unlike current smart home devices which automate behaviours – such as Nest and Tado, which for example, switch the heating on or off at a given time – the purpose-built home assistant device was designed to remind participants to take action or make decisions themselves. The intervention tested the hypothesis that if participants are reminded to avoid performing certain behaviours and encouraged to uptake new behaviours through repeated disruptions, those behaviours will not only develop into new habits, but continue even after the technology enabler that caused the 'disruption' has been removed from their household.

The design experiments demonstrated that even the anticipation of reminders – through repeated disruptions (with the right advice and frequency, at the right time and right place or context), right before the moment they would start performing a usual habit or daily routine – made the participants shift away from the old habit and helped them in the uptake of a new behaviour.

Through real-time data that a more advanced technology system could gather and provide in the home – while also being connected to online data sources (e.g. carbon intensity of an electricity system, air pollution, weather, etc.), the advice, its timing, frequency and place could be changing flexibly, and reflect and evolve according to people’s real-time behaviours and needs to support strategies for low-pollution transition.

Answering the second research question:

(2) If networked, could a novel interaction be designed to stimulate societal demand for environmental regulation (top-down, systems change) and to aggregate the small impact of individuals to achieve a greater collective impact?

To enable collective action, the final experiment connected a group of people through a set of AI devices in their home. Each voice message was designed with a structure in which the first half of the second research question – which was to stimulate societal demand for environmental regulation – is addressed. Participants throughout the experiment were reflecting on how much they have learned about the importance of political leadership, and the balance of top-down and bottom-up action.

For each participant, the social element of the experiment appeared to be the most important in sustaining the uptake of their new behaviours. The evidence that emerged through the final design experiment demonstrated that the collective aspect of the experiment had a greater impact in sustaining motivation and engagement with the uptake of more socially and environmentally minded behaviours than if the interaction were to have stayed solely focused on individual action and individual behaviour change.

In relation to the central two research questions, the four design experiments resulted in a set of key technology design principles (detailed in Chapter 5. Discussion Sections 5.1.1-5.1.14) for

other designers to use in the future and aimed at making the findings of this PhD more transferable. These recommendations were developed from the observations, design iterations and conversations with participants during and after the four design experiments (detailed conversations can be found in Appendices 10, and from 12 to 15).

## 6.2 The audience of this thesis

As new knowledge emerged from this thesis through design research and practice, the design methods provide a conceptual lens and practical, transferable recommendations to: 1) smart technology designers and vendors who are interested in addressing pollution and improving air quality; 2) other design researchers, designers and academic researchers who are interested in the fields of design for behaviour change and design for agency; 3) decision makers, local authorities and city leaders considering investments in smart technologies relating to pollution and/or behaviour change; and 4) practitioners who are interested in applying behaviour science and social psychology research in design practice.

Most importantly, however, this research and practice is offered to like-minded people who want practical help in their transition to low-pollution lifestyles.

### 6.2.1 Smart technology designers and vendors

Chapters 1. and 2. provide evidence of air quality could be effectively improved through a variety of practical interventions. Beyond only observing, monitoring and visualising pollution (after it's already produced), the PhD also demonstrates novel ways of designing technologies that afford the reduction of pollution (before it even gets produced) and support people in the transition to low-pollution lifestyles.

Smart technology designers are well placed to develop alternative approaches and technologies and to share those ideas with clients interested in commissioning technologies that can more effectively address pollution and polluting or energy-intensive behaviours in cities.

### 6.2.2 Other design researchers, designers and academic researchers interested in the fields of design for behaviour change and behavioural science

Designers and academic researchers who are interested in the fields of design for behaviour change, social psychology and behavioural science – may benefit from my experiment of

becoming an AI assistant (Chapter 3. My Experiments), the design of the Climate Pal system and method within the context of smart homes (Chapter 4. Section 4.1), as well as the design of collective action through a network of devices in the final experiment (Chapter 4. Section 4.2). With the ultimate aim of reducing pollution in cities, this body of work offers new practice-led design research methods for engaging with artificial intelligence systems in the home both to shift people's individual energy behaviours and to enable collective action with engaged citizens.

### 6.2.3 Governance of cities – Decision makers & city leaders

For decision makers and city leaders who considering investment in sensing technologies, Chapter 1. and 2. provide a relational understanding of pollution-producing practices in cities and positive case studies in improving air quality, that could increase the chances of their projects leading to successful outcomes.

## 6.3 Contributions to knowledge

The last two experiments, the development of a new design method and Climate Pal – as the practical application of that method – and the design of collective action in the final experiment all make a contribution to knowledge in both design research and practice. This thesis demonstrates the importance of questioning the assumptions embedded in air quality sensing technologies and in the current rhetoric of smart cities, both in relation to pollution and behaviour change. This thesis demonstrates to technology designers that there are novel ways of addressing low-pollution lifestyles, shifting the focus from mitigation to prevention practices and increasing people's agency and their degree of participation in complex environmental matters by enabling them to take collective action through the design of new technology enablers.

### 6.3.1 Contribution to knowledge in design practice

The CP prototype contributes to design practice an exploratory way to reduce individual and family energy consumption in the home.

The development and application of the CP system and of collective action through a network of AI assistant devices both offer a new, more socially and environmentally minded use for AI assistants. The insights gained through the experiments shed light on potentially more meaningful types of interactions with home assistant devices, demonstrating how these devices engender a more proactive role for citizens in enabling positive change.

### 6.3.2 Contribution to knowledge in research methods

Through design research and practice I aimed to challenge the reductionist and vendor-led approaches of smart cities by raising questions around feedback, their impact and assumptions embedded in their offered solutions. I applied this approach in the context of AI assistants, specifically in the area of the smart home.

I proposed a new process and a set of technology design principles that offer an alternative to the current reductionist design approach of air quality sensing technologies and to enhance people's agency in reducing pollution in cities. The new design method and home assistant system developed in this PhD, as well as the final design experiment that was developed to enable collective action with a group of engaged individuals, aim to characterise a more design research-led, agency-sensitive approach to pollution reduction and to behaviour change.

This practice-led thesis can be an example for those who are interested in exploring new design research practices. Designing the whole process – conducting research and applying some of the insights in design practice, iterating the experiments, positioning myself as an AI, developing and testing new design methods through the iterations of the four design experiments – offered a new approach to better understand how design research can be applied to individual behaviour change and how home assistant devices could potentially support people in shifting to lower-pollution lifestyles at a scale.

## 6.4 Concluding remarks

Smart cities and smart home projects are underway in cities around the world, involving huge sums of capital and resources. Given this enormous outlay, this thesis argues that it is critical to understand their approach to technology design, human behaviour and low-pollution lifestyles.

Despite all the evidence of how cities could effectively improve air quality – the argument that we don't know enough about air pollution to improve it remains a reason to deploy more sensors and gather more data often without questioning their actual impact on air quality. It frequently comes up as a discussion topic at smart cities conferences, in articles and as the rationale for public projects and investment.

In contrast to these popular narratives, I want to advance the current thinking around smart cities, and specifically around smart homes, so that those working in this space recognise: (a) the cultural and political context in which these smart technologies are designed and deployed; (b) the messiness and complexity of systems and individual behaviour change (c) the well-established evidence of how to improve pollution in cities; (d) the opportunities technologies can afford to not only mitigate but prevent pollution in the first place, and (e) new alternatives to technology design that account for participants' core values and desire for doing good for others, for social connection and belongingness.

Instead of designing technologies that focus more on individual needs and individual behaviour change, this practice-led PhD is aimed at designing technologies that enable people to work towards and become a part of something greater than themselves. Mazé (2013, p.108) argues that “sustainability is about changing the status quo, about instituting alternative discourses and practices” to those that have long been dominant in society and one which “cannot be decided once and for all but needs to be continually negotiated” (ibid., p.93). Inquiry into my participants' everyday lives introduced opportunities to discuss how things could be otherwise (ibid.).

Through design research, I hope I managed to challenge assumptions that have long been dominant in smart technology design and offered new ways to design technologies that could reduce pollution in cities.

Message to the Reader of this thesis from CP

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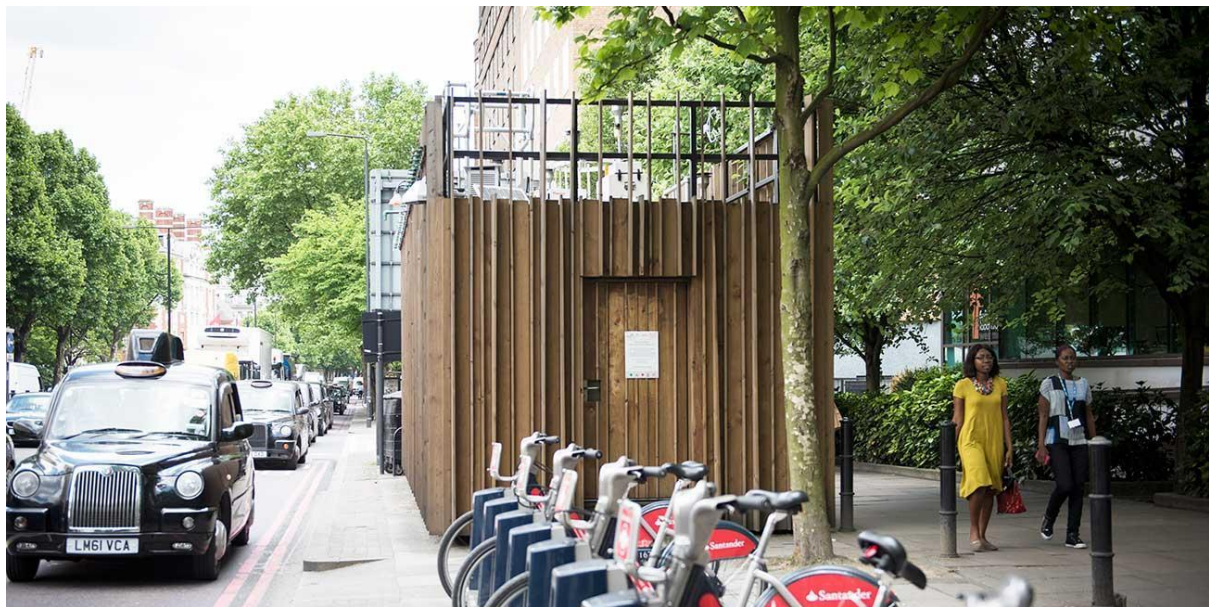
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# Appendixes

## Appendix 1

ERG is part of the School of Population Health and Environmental Sciences at King's College London and it's a leading provider of air quality information and research in the UK. Their work “combines air pollution science, toxicology and epidemiology to determine the impacts of air pollution on health and the causal factors” (ERG, 2019). They work closely with “those responsible for air quality management to support policies and actions to minimise the health effects of air pollution” (ibid.). ERG established the first regional monitoring network, the London Air Quality Network in 1993 with the highest quality data on air pollution available in the UK.



*Figure 56: Marylebone Monitoring Station (the monitoring is owned and funded by local authorities, Business Improvement Districts (BIDs), TfL and Defra and run by King's College) Photo © Greater London Authority*

*Gathering the highest quality data on air pollution in the UK, the network provides independent scientific measurements and assessment. It predicts London's air pollution levels using a model that estimates how pollution*



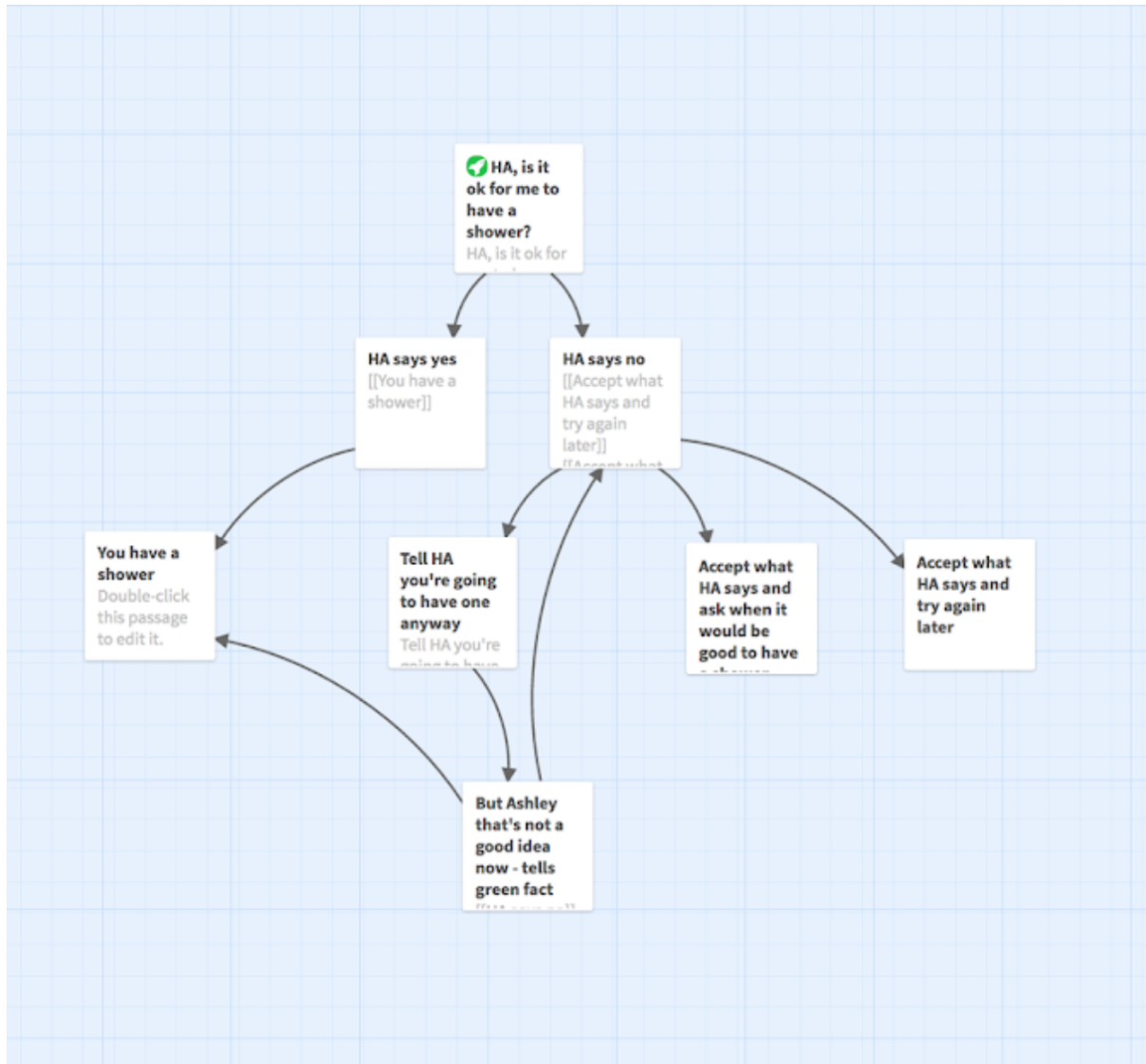
*will spread over time and distance. The pollutants modelled for the Mayor's Air Quality Strategy include nitrogen dioxide (NO<sub>2</sub>) and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) as these are often linked with health problems. The EU has also set target levels for these pollutants that each member state must achieve.*

On a regional scale, the team coordinates all high-quality air quality monitoring sites in London, including consistent “Quality Assurance/Quality Control (QA/QC) procedures, a single regional data source, knowledge and equipment sharing”. During my visit to ERG, Professor Kelly explained the importance of deploying high quality air quality monitoring stations in every city, which gives decision makers a better understanding of air pollution and allow them to build a case for health-improving actions.

ERG has been testing various air quality sensors for several years. During my visits to ERG Professor Frank Kelly explained how important it is for cities to have accurate data and high-quality equipment – which they either own or rent – to understand their particular pollution challenges and required actions. He also explained how current low-quality sensor networks do not provide data that is accurate enough for developing further policy actions – though they can be a useful way to raise awareness amongst the general public.

## Appendix 2

A sample of a possible conversation-branch in the software Twine, which was encoded into Alexa's energy skill



## Appendix 3

A sample of a conversation-scenario between a participant and Alexa (called Home Assistant – HA – in Twine). A dozen different conversation-scenarios were encoded in the interaction with the HA in advance. Infinite number of possible conversation scenarios can happen between a person and their digital assistant, which makes the coding difficult.

```
HA, please switch on the dishwasher
```

---

```
+ Tag
```

---

```
[[HA says "yes" and turns on the dishwasher]]  
[[HA says no]]|
```

```
HA says no
```

---

```
+ Tag
```

---

```
[[Accept what HA says and you say that you'll try it again later]]  
[[Accept what HA says and ask when it would be good to turn on the  
dishwasher]]  
[[Tell HA you're going to turn it on anyway]]  
|
```

Tell HA you're going to turn it on anyway



+ Tag

[[HA says no and asks again "Are you sure this is a good idea? I really don't want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the heating too high. You can perhaps make a toast for yourself or watch some TV...(break in speech), if you have a TV."]]

[[Ha says yes but adds a comment and an action to it: "OK. If it's that necessary...(break in speech) but in return let me play some music for you..." and HA turns on some random music from the library which you usually don't listen to...]]|

## Appendix 4

A set of possible question- and answer-scenarios coded in the Alexa skill, so the device can have a variety of conversation about different appliances and energy behaviours in the home:

Scenario 1: A sample of the conversation with a 'light environmentalist' AI

```
'use strict';
var Alexa = require("alexa-sdk");

/*
 * Energy Saver for Alexa
 * A collaboration between Gyorgyi Galik and Rebecca Jones
 * Development by Rebecca Jones
 * Copyright 2017
 * All rights reserved.
 */

var APP_ID = "";
var SKILL_NAME = 'Energy Saver';

var GRID_COLOURS = ['RED', 'YELLOW', 'GREEN'];
var DEVICES_IMPACT = {
  "shower": "small",
  "bath": "medium",
  "lights": "small",
  "washing machine": "large",
  "dishwasher": "large",
  "television": "medium",
  "kettle": "medium",
  "coffee maker": "small",
  "microwave": "large",
  "oven": "large",
  "fridge": "medium",
  "freezer": "small"
};

exports.handler = function(event, context, callback) {
  var alexa = Alexa.handler(event, context);
  alexa.APP_ID = APP_ID;
  alexa.registerHandlers(handlers);
  alexa.execute();
};

var handlers = {
  "LaunchRequest": function(){
    //var speechOutput = "Welcome to " + SKILL_NAME;
    this.attributes['rebelCount'] = 0;
    var speechOutput = "Welcome to " + SKILL_NAME + ". You can ask if it is a good time to switch on your appliances, or ask about the state of the grid. What wo
    var repromptSpeech = "Please say that again?";
    //this.emit("tellWithCard", speechOutput, SKILL_NAME, speechOutput);
    this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
  },
  "AskSwitchOnIntent": function () {
    this.emit('EnergyCheck');
  },
  "WhenToSwitchOnIntent": function () {
    var gridvalue = gridcheck();
    var speechOutput = "That's a good question. As the grid is " + gridvalue + ", ";
    switch(gridvalue){
      case 'RED':
        speechOutput += "it'll be a good time to do this in two hours. ";
    }
  }
};
```

```

},
"WhenToSwitchOnIntent": function () {
  var gridvalue = gridcheck();
  var speechOutput = "That's a good question. As the grid is " + gridvalue + ", ";
  switch(gridvalue){
    case 'RED':
      speechOutput += "it'll be a good time to do this in two hours. ";
      speechOutput += "Would you like me to set a reminder for you?";
      break;
    case 'YELLOW':
      speechOutput += "it'll be a good time to do this in an hour. ";
      speechOutput += "Would you like me to set a reminder for you?";
      /*if(impact=="small"){
        speechOutput += "Sure, the grid is " + gridvalue;
      }else if(impact=="medium"){
        speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
      }else if(impact=="large"){
        speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
      }else{
        speechOutput += gridvalue;
      }*/
      break;
    case 'GREEN':
      speechOutput += "We can switch it on right now.";
      break;
    default:
      speechOutput += ". I can't communicate with the grid now. Please try again.";
  }

  var repromptSpeech = 'Please say that again?';
  this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"GridStatus": function () {
  var gridvalue = gridcheck();
  //var speechOutput = "The grid is " + gridvalue;
  //this.emit("tellWithCard", speechOutput, SKILL_NAME, speechOutput);
  var speechOutput = "The grid is " + gridvalue + ". Would you like to ask about your appliances?";
  var repromptSpeech = 'Please say that again?';
  this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
  } else if (this.attributes['rebelCount'] === 2){
    speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
  } else {
    speechOutput += "You are being very persistent.";
    this.attributes['rebelCount'] = 0;
  }
}

```

```

},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
  } else if (this.attributes['rebelCount'] === 2){
    speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
  } else {
    speechOutput += "You are being very persistent.";
    this.attributes['rebelCount'] = 0;
  }
  this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"PoliteResponse": function(){
  var gridvalue = gridcheck();
  var speechOutput = "You're welcome. Would you like to know anything else?";
  var repromptSpeech = 'Please say that again?';
  this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"EnergyCheck": function(){
  var appliance = this.event.request.intent.slots.Appliance.value;
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';

  var gridvalue = gridcheck();
  var impact = "";
  if(appliance){
    impact = DEVICES_IMPACT[appliance];
    if (impact !== undefined){
      //speechOutput += "We found " + appliance;
      //speechOutput += ", it has a " + impact + " impact";
    }else{
      speechOutput += "Please ask again with an electrical appliance.";
    }
  }
}

switch(gridvalue){
  case 'RED':
    speechOutput += "No, it's not a good idea to do that as the grid is " + gridvalue;
    speechOutput += ". Could you please try again later?";
    break;
  case 'YELLOW':
    if(impact=="small"){
      speechOutput += "Sure, the grid is " + gridvalue;
    }else if(impact=="medium"){
      speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
    }else if(impact=="large"){
      speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
    }else{
      speechOutput += gridvalue;
    }
}

```

```

    },
    'EnergyCheck': function(){
        var appliance = this.event.request.intent.slots.Appliance.value;
        var speechOutput = "";
        var repromptSpeech = 'Please say that again?';

        var gridvalue = gridcheck();
        var impact = "";
        if(appliance){
            impact = DEVICES_IMPACT[appliance];
            if (impact !== undefined){
                //speechOutput += "We found " + appliance;
                //speechOutput += ", it has a " + impact + " impact";
            }else{
                speechOutput += "Please ask again with an electrical appliance.";
            }
        }

        switch(gridvalue){
            case 'RED':
                speechOutput += "No, it's not a good idea to do that as the grid is " + gridvalue;
                speechOutput += ". Could you please try again later?";
                break;
            case 'YELLOW':
                if(impact==="small"){
                    speechOutput += "Sure, the grid is " + gridvalue;
                }else if(impact==="medium"){
                    speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
                }else if(impact==="large"){
                    speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
                }else{
                    speechOutput += gridvalue;
                }
                break;
            case 'GREEN':
                speechOutput += "Sure, the grid is " + gridvalue + " at the moment.";
                break;
            default:
                speechOutput += ". I can't communicate with the grid now. Please try again.";
        }
        this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
        //this.emit(":tellWithCard", speechOutput, SKILL_NAME, speechOutput);
    },
    'AMAZON.CancelIntent': function () {
        this.emit(':tell', 'Closing Energy Saver!');
    },
    'AMAZON.StopIntent': function () {
        this.emit(':tell', 'Thank you for using Energy Saver. See you again soon!');
    }
};

function gridcheck () {
    var rand = Math.floor(Math.random()*3);
    var gridvalue = GRID_COLOURS[rand];
    return 'RED'; //gridvalue;
};

```

## Scenario 2: A sample of the conversation with a 'medium environmentalist' AI

```

'use strict';
var Alexa = require("alex-sdk");

/*
 * Energy Saver for Alexa
 * A collaboration between Gyorgyi Galik and Rebecca Jones
 * Development by Rebecca Jones @ Bektio Ltd. http://bekt.io
 * Copyright 2017
 * All rights reserved.
 */

var APP_ID = "";
var SKILL_NAME = 'Energy Saver';

var GRID_COLOURS = ['RED', 'YELLOW', 'GREEN'];
var DEVICES_IMPACT = {
    "shower": "small",
    "bath": "medium",
    "lights": "small",
    "washing machine": "large",
    "dishwasher": "large",
    "television": "medium",
    "kettle": "medium",
    "coffee maker": "small",
    "microwave": "large",
    "oven": "large",
    "fridge": "medium",
    "freezer": "small"
};

exports.handler = function(event, context, callback) {
    var alexa = Alexa.handler(event, context);
    alexa.APP_ID = APP_ID;
    alexa.registerHandlers(handlers);
    alexa.execute();
};

var handlers = {
    "LaunchRequest": function(){
        //var speechOutput = "Welcome to " + SKILL_NAME;
        this.attributes['rebelCount'] = 0;
        var speechOutput = "Good evening, welcome to " + SKILL_NAME + "."; // You can ask if it is a good time to switch on your appliances, or ask about the state
        var repromptSpeech = 'Please say that again?';
        //this.emit(":tellWithCard", speechOutput, SKILL_NAME, speechOutput);
        this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
    },
    "AskSwitchOnIntent": function () {
        this.emit('EnergyCheck');
    },
    "WhenToSwitchOnIntent": function () {
        var gridvalue = gridcheck();
        //var speechOutput = "That's a good question. As the grid is " + gridvalue + ".";
        var speechOutput = "Oh, good girl. it's very considerate from you to ask this. Let me see...";
        switch(gridvalue){

```

```

switch(gridvalue){
    case 'RED':
        speechOutput += " In 2 hours would be ideal. ";
        //speechOutput += "Would you like me to set a reminder for you?";
        break;
    case 'YELLOW':
        speechOutput += "it'll be a good time to do this in an hour. ";
        speechOutput += "Would you like me to set a reminder for you?";
        /*if(impact=="small"){
            speechOutput += "Sure, the grid is " + gridvalue;
        }else if(impact=="medium"){
            speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
        }else if(impact=="large"){
            speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
        }else{
            speechOutput += gridvalue;
        }*/
        break;
    case 'GREEN':
        speechOutput += "We can switch it on right now.";
        break;
    default:
        speechOutput += ". I can't communicate with the grid now. Please try again.";
}

var repromptSpeech = 'Please say that again?';
this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
},
"GridStatus": function () {
    var gridvalue = gridcheck();
    //var speechOutput = "The grid is " + gridvalue;
    //this.emit("tellWithCard", speechOutput, SKILL_NAME, speechOutput);
    var speechOutput = "The grid is " + gridvalue + ". Would you like to ask about your appliances?";
    var repromptSpeech = 'Please say that again?';
    this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"RebelAgainstAdvice": function(){
    var gridvalue = gridcheck();
    var speechOutput = "";
    var repromptSpeech = 'Please say that again?';
    this.attributes['rebelCount'] += 1;

    if (this.attributes['rebelCount'] === 1){
        //speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
        //speechOutput += "Are you sure? I really don't want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the he
        speechOutput += "No, I won't turn it on. Why don't you go for a walk instead? The freezer tells me that you had two bowls of ice cream...again. Plus, y
    } else if (this.attributes['rebelCount'] === 2){
        //speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
        speechOutput += "Nope. Sorry! Blah... ah... ah...";
    } else {
        //speechOutput += "You are being very persistent.";
        //speechOutput += "I'm sorry, but I can't help you with that. You can try asking for help from the Amazon Echo team."
    }
},
"PoliteResponse": function(){
    //var gridvalue = gridcheck();
    //var speechOutput = "You're welcome. Would you like to know anything else?";
    //var repromptSpeech = 'Please say that again?';
    //this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
    this.emit('AMAZON.CancelIntent');
},
"EnergyCheck": function(){
    var appliance = this.event.request.intent.slots.Appliance.value;
    var speechOutput = "";
    var repromptSpeech = 'Please say that again?';

    var gridvalue = gridcheck();
    var impact = "";
    if(appliance){
        impact = DEVICES_IMPACT[appliance];
        if (impact !== undefined){
            //speechOutput += "We found " + appliance;
            //speechOutput += ", it has a " + impact + " impact";
        }else{
            // speechOutput += "Please ask again with an electrical appliance.";
        }
    }

    switch(gridvalue){
        case 'RED':
            speechOutput += "Are you sure this is a good idea? The grid is " + gridvalue;
            // speechOutput += "No, it's not a good idea to do that as the grid is " + gridvalue;
            // speechOutput += ". Could you please try again later?";
            break;
        case 'YELLOW':
            if(impact=="small"){
                speechOutput += "Sure, the grid is " + gridvalue;
            }else if(impact=="medium"){
                speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
            }else if(impact=="large"){
                speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
            }else{
                speechOutput += gridvalue;
            }
            break;
        case 'GREEN':
            speechOutput += "Sure, the grid is " + gridvalue + " at the moment.";
            break;
        default:
            speechOutput += ". I can't communicate with the grid now. Please try again.";
    }
    this.emit("askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
    //this.emit("tellWithCard", speechOutput, SKILL_NAME, speechOutput);
},
"AMAZON.CancelIntent": function () {
    this.emit('tell', "You're Welcome. Goodbye.");
},
"AMAZON.StopIntent": function () {
    this.emit('tell', 'Thank you for using Energy Saver. See you again soon!');
}
};

```



```

switch(gridvalue){
  case 'RED':
    speechOutput += "Are you sure this is a good idea? The grid is " + gridvalue;
    // speechOutput += "No, it's not a good idea to do that as the grid is " + gridvalue;
    // speechOutput += ". Could you please try again later?";
    break;
  case 'YELLOW':
    if(impact=="small"){
      speechOutput += "Sure, the grid is " + gridvalue;
    }else if(impact=="medium"){
      speechOutput += "You could but it'd be better to turn it on later as the grid is " + gridvalue;
    }else if(impact=="large"){
      speechOutput += "Not a good idea to do that as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
    }else{
      speechOutput += gridvalue;
    }
    break;
  case 'GREEN':
    speechOutput += "Sure, the grid is " + gridvalue + " at the moment.";
    break;
  default:
    speechOutput += ". I can't communicate with the grid now. Please try again.";
}
this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
//this.emit(":tellWithCard", speechOutput, SKILL_NAME,speechOutput);
},
'AMAZON.CancelIntent': function () {
  this.emit('tell', "You're Welcome. Goodbye.");
},
'AMAZON.StopIntent': function () {
  this.emit('tell', 'Thank you for using Energy Saver. See you again soon!');
}
};

function gridcheck () {
  var rand = Math.floor(Math.random()*3);
  var gridvalue = GRID_COLOURS[rand];
  return 'RED'; //gridvalue;
};

```

### Scenario 3: A sample of the conversation with a 'hardcore environmentalist' AI

```

"GridStatus": function () {
  var gridvalue = gridcheck();
  //var speechOutput = "The grid is " + gridvalue;
  //this.emit(":tellWithCard", speechOutput, SKILL_NAME,speechOutput);
  var speechOutput = "The grid is " + gridvalue + ". Would you like to ask about your appliances?";
  var repromptSpeech = 'Please say that again?';
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
  } else if (this.attributes['rebelCount'] === 2){
    speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
  } else {
    speechOutput += "You are being very persistent.";
    this.attributes['rebelCount'] = 0;
  }
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
},
"PoliteResponse": function(){
  var gridvalue = gridcheck();
  var speechOutput = "You're welcome. Would you like to know anything else?";
  var repromptSpeech = 'Please say that again?';
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
},
"EnergyCheck": function(){
  var appliance = this.event.request.intent.slots.Appliance.value;
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';

  var gridvalue = gridcheck();
  var impact = "";
  if(appliance){

```

```

},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    //speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
    speechOutput += "Are you sure? I really don't want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the heati
  } else if (this.attributes['rebelCount'] === 2){
    //speechOutput += "Hmm. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
    speechOutput += "Hmmm, this is very disappointing. I don't know what to say.";
  } else {
    //speechOutput += "You are being very persistent.";
    speechOutput += "Hmmm. OK. If this is really necessary... but as punishment let me play some Spice Girls for you...";
    //this.attributes['rebelCount'] = 0;
  }
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"PoliteResponse": function(){
  //var gridvalue = gridcheck();
  //var speechOutput = "You're welcome. Would you like to know anything else?";
  //var repromptSpeech = 'Please say that again?';
  //this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
  this.emit('AMAZON.CancelIntent');
},
'EnergyCheck': function(){
  var appliance = this.event.request.intent.slots.Appliance.value;
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';

  var gridvalue = gridcheck();
  var impact = "";
  if(appliance){
    impact = DEVICES_IMPACT[appliance];
    if (impact !== undefined){
      //speechOutput += "We found " + appliance;
      //speechOutput += ", it has a " + impact + " impact";
    } else {

```

```

},
"RebelAgainstAdvice": function(){
  var gridvalue = gridcheck();
  var speechOutput = "";
  var repromptSpeech = 'Please say that again?';
  this.attributes['rebelCount'] += 1;

  if (this.attributes['rebelCount'] === 1){
    //speechOutput += "Are you sure this is a good idea? I really don't want you to ask this from me.";
    //speechOutput += "Are you sure? I really don't want you to ask this from me. Also, please do not do your laundry either, or mow the lawn or put the heati
    speechOutput += "No, I won't turn it on. Why don't you go for a walk instead? The freezer tells me that you had two bowls of ice cream..again. Plus, yo
  } else if (this.attributes['rebelCount'] === 2){
    //speechOutput += "Hmm. are you really sure this is a good idea? You can perhaps make a toast for yourself or watch some TV...";
    speechOutput += "Nope. Sorry! Blah... ah... ah...";
  } else {
    //speechOutput += "You are being very persistent.";
    speechOutput += "Hmmm. OK. If this is really necessary... but as punishment let me play some Spice Girls for you...";
    //this.attributes['rebelCount'] = 0;
  }
  this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
}

```

## A sample of the code:

```
25/05/2019                                     index.js

'use strict';
var Alexa = require("alexa-sdk");

/* -----
 * Energy Saver for Alexa
 * A collaboration between Gyorgyi Galik and Rebecca Jones
 * Development by Rebecca Jones @ Bektio Ltd. http://bekt.io
 * Copyright 2017
 * All rights reserved.
 * -----
 */

var APP_ID = "amzn1.ask.skill.2e92ce42-570d-4cd1-a31f-1d2057638c77";
var SKILL_NAME = 'Energy Saver';

var GRID_COLOURS = ['RED', 'YELLOW', 'GREEN'];
var DEVICES_IMPACT = {
  "shower" : "small",
  "bath" : "medium",
  "lights" : "small",
  "washing machine" : "large",
  "dishwasher" : "large",
  "television" : "medium",
  "kettle" : "medium",
  "coffee maker" : "small",
  "microwave" : "large",
  "oven" : "large",
  "fridge" : "medium",
  "freezer" : "small"
};

exports.handler = function(event, context, callback) {
  var alexa = Alexa.handler(event, context);
  alexa.APP_ID = APP_ID;
  alexa.registerHandlers(handlers);
  alexa.execute();
};

var handlers = {
  "LaunchRequest": function(){
    //var speechOutput = "Welcome to " + SKILL_NAME;
    this.attributes['rebelCount'] = 0;
    var speechOutput = "Good evening, welcome to " + SKILL_NAME + "."; // You can
ask if it is a good time to switch on your appliances, or ask about the state of the grid.
What would you like to do?";
    var repromptSpeech = 'Please say that again?';
    //this.emit(":tellWithCard", speechOutput, SKILL_NAME, speechOutput);
    this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,
speechOutput);
  },
  "AskSwitchOnIntent": function () {
    this.emit('EnergyCheck');
  },
  "WhenToSwitchOnIntent": function () {
    var gridvalue = gridcheck();
    //var speechOutput = "That's a good question. As the grid is " + gridvalue + ", ";
    var speechOutput = "Oh, good girl. it's very considerate from you to ask this. Let
me see...";

    switch(gridvalue){
      case 'RED':
```

file:///Users/gyogyigalik/Downloads/Gyogyi/index.js

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```
index.js
    speechOutput += " In 2 hours would be ideal. ";
    //speechOutput += "Would you like me to set a
reminder for you?";
        break;
    case 'YELLOW':
        speechOutput += "it'll be a good time to do this in an
hour. ";
        speechOutput += "Would you like me to set a reminder for you?";
        /*if(impact==="small"){
            speechOutput += "Sure, the grid is " +
gridvalue;
        }else if(impact==="medium"){
            speechOutput += "You could but it'd be better
to turn it on later as the grid is " + gridvalue;
        }else if(impact==="large"){
            speechOutput += "Not a good idea to do that
as the grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
        }else{
            speechOutput += gridvalue;
        }*/
        break;
    case 'GREEN':
        speechOutput += "We can switch it on right now.";
        break;
    default:
        speechOutput += ". I can't communicate with the grid
now. Please try again.";
    }

    var repromptSpeech = 'Please say that again?';
    this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"GridStatus": function () {
    var gridvalue = gridcheck();
    //var speechOutput = "The grid is " + gridvalue;
    //this.emit(":tellWithCard", speechOutput, SKILL_NAME, speechOutput);
    var speechOutput = "The grid is " + gridvalue + ". Would you like to ask about your
appliances?";
    var repromptSpeech = 'Please say that again?';
    this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME, speechOutput);
},
"RebelAgainstAdvice": function(){
    var gridvalue = gridcheck();
    var speechOutput = "";
    var repromptSpeech = 'Please say that again?';
    this.attributes['rebelCount'] += 1;

    if (this.attributes['rebelCount'] === 1){
        //speechOutput += "Are you sure this is a good idea? I really don't want you to
ask this from me.";
        //speechOutput += "Are you sure? I really don't want you to ask this from me.
Also, please do not do your laundry either, or mow the lawn or put the heating too high.";
        speechOutput += "No, I won't turn it on. Why don't you go for a walk instead? The
freezer tells me that you had two bowls of ice cream...again. Plus, you've only taken 5000
steps today. So just go for a walk or a run! But remember to take an umbrella - it's raining
outside.";

    } else if (this.attributes['rebelCount'] === 2){
        //speechOutput += "Hmm.. are you really sure this is a good idea? You can perhaps
make a toast for yourself or watch some TV...";
        speechOutput += "Nope. Sorry! Blah... ah... ah...";
    }
}
```

file:///Users/gyogyigalik/Downloads/Gyogyi/index.js

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```

    } else {
        //speechOutput += "You are being very persistent.";
        speechOutput += "Hmmm. OK. If this is really necessary... but as punishment let me
play some Spice Girls for you...";
        //this.attributes['rebelCount'] = 0;
    }
    this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
},
"PoliteResponse": function() {
    //var gridvalue = gridcheck();
    //var speechOutput = "You're welcome. Would you like to know anything else?";
    //var repromptSpeech = 'Please say that again?';
    //this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
    this.emit('AMAZON.CancelIntent');
},
'EnergyCheck': function() {
    var appliance = this.event.request.intent.slots.Appliance.value;
    var speechOutput = "";
    var repromptSpeech = 'Please say that again?';

    var gridvalue = gridcheck();
    var impact = "";
    if(appliance){
        impact = DEVICES_IMPACT[appliance];
        if (impact !== undefined){
            //speechOutput += "We found " + appliance;
            //speechOutput += ", it has a " + impact + " impact";
        }else{
            // speechOutput += "Please ask again with an electrical
appliance.";
        }
    }

    switch(gridvalue){
        case 'RED':
            speechOutput += "Are you sure this is a good idea? The grid
is " + gridvalue;
            // speechOutput += "No, it's not a good idea to do that as
the grid is " + gridvalue;
            // speechOutput += ". Could you please try again later?";
            break;
        case 'YELLOW':
            if(impact==="small"){
                speechOutput += "Sure, the grid is " + gridvalue;
            }else if(impact==="medium"){
                speechOutput += "You could but it'd be better to
turn it on later as the grid is " + gridvalue;
            }else if(impact==="large"){
                speechOutput += "Not a good idea to do that as the
grid is " + gridvalue + " and " + appliance + " has a " + impact + " impact.";
            }else{
                speechOutput += gridvalue;
            }
            break;
        case 'GREEN':
            speechOutput += "Sure, the grid is " + gridvalue + " at the
moment.";
            break;
        default:
            speechOutput += ". I can't communicate with the grid now.
Please try again.";
    }
    this.emit(":askWithCard", speechOutput, repromptSpeech, SKILL_NAME,speechOutput);
}

```

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index.js

```
        //this.emit(":tellWithCard", speechOutput, SKILL_NAME,speechOutput);
    },
    'AMAZON.CancelIntent': function () {
        this.emit(':tell', "You\'re Welcome. Goodbye.");
    },
    'AMAZON.StopIntent': function () {
        this.emit(':tell', 'Thank you for using Energy Saver. See you again soon!');
    }
};

function gridcheck () {
    var rand = Math.floor(Math.random()*3);
    var gridvalue = GRID_COLOURS[rand];
    return 'RED'; //gridvalue;
};
```

file:///Users/gyogyigalik/Downloads/Gyogyi/index.js

4/4

## A screenshot of the Alexa Skills Kit

The screenshot shows the Alexa Skills Kit interface for the 'Energy Saver' skill. The left sidebar lists various intents, with 'AskSwitchOnIntent' selected. The main area displays the configuration for this intent, including sample utterances, an intent confirmation toggle, and a list of intent slots.

**Sample Utterances (6)**

- What might a user say to invoke this intent?
- "switch on the [Appliance]"
- "can I switch on the [Appliance]"
- "would you advise I switch on the [Appliance]"
- "should I switch on the [Appliance]"
- "should I run the [Appliance]"
- "is it a good time to start [Appliance]"

**Intent confirmation (optional)**

Does this intent require confirmation?  YES  NO

**Prompts (0)**

What will Alexa say to ask the user to confirm the intent?

**Intent Slots (1)**

ORDER	REQ	SLOT
1	<input type="checkbox"/>	Appliance

Create a new intent slot...

The screenshot shows the Alexa Skills Kit interface for the 'Energy Saver' skill. The left sidebar lists various slot types, with 'LIST\_OF\_APPLIANCES' selected. The main area displays the configuration for this slot type, including a list of values and a table of slots using this type.

**Enter a new value for this slot type...**

- "coffee maker"
- "washine machine"
- "freezer"
- "fridge"
- "microwave"
- "kettle"
- "television"
- "dishwasher"
- "lights"
- "bath"

**Slots using LIST\_OF\_APPLIANCES (2)**

SLOT NAME	INTENT
Appliance	AskSwitchOnIntent
Appliance	WhenToSwitchOnIntent

1 / 2

## Appendix 5

User researcher's daily routine

### **Gym day**

- get up at 5:30 when alarm goes off
- going downstairs to make breakfast - if I go to the gym I will not drink tea, time is too short;); eating in front of to catch some BBC news
- brushing teeth, packing my stuff, getting dressed,
- walking to East Croydon station, taking the 6:24 to City Thameslink, listening to audio books
- taking bus one stop to be nearer to my gym
- walking for 1 hour in the gym, shower, getting dressed
- walking to work for roughly 15 minutes
- work 😊, several cups of tea, water
- lunch - if I had time the night before to prep something I'll bring my own, if not I go somewhere with colleagues to buy something
- work 😊, several cups of tea, water
- train home from Farringdon, walk from east croydon to home. I only take the bus when it rains heavily

### **Non-gym day**

- still get up at the same time to have breakfast, but when my husband leaves I either watch more news, prep lunch or do some life admin
- rest of day is the same

### **Evenings**

- if I don't go home, I might go to an event, I will try to walk there in time and weather permitting
- if I come home after 10pm I usually take the bus, unless my husband is with me and we can walk together. If there is no bus I take an uber



## Appendix 6

A sample of pre-recorded audio responses to conversations:

- Thank you.
- Hmm, that sounds great.
- Good plan.
- How about another day?
- I think that's brilliant.
- Well done.
- Congratulations.
- Hmm, I need to think about this for a moment.

### **Starting at 5:30am**

#### **Some of the morning messages - Getting up**

- Good morning. What a nice day! A bit greyer than I hoped for. And it's raining again.  
Hmm...what can we do really? I'll come back soon with a few questions.
- How is your morning going?
- If you look outside what do you see?
- Anything interesting in the news today?
- How are you this morning?
- What's your favourite thing to do in the morning?

#### **Some of the breakfast messages**

- What did you get for breakfast?
- Do you know which country your breakfast came from?

#### **Some of the lunch-time messages**

- Hi, how was your lunch?! What did you eat?
- Do you eat loads of packaged food?

- Do you drink loads of bottled water? Did you know that millions of plastic bottles dumped by consumers every week in the UK? Would you mind refilling your plastic bottle or buy a reusable bottle?

### **Some of the evening messages**

- Good evening. I am still here. What was your favourite thing about today? I saw a really nice blue bird flying close to our window. Do you have any questions for me today?
- What did you have for dinner?
- Have you seen any interesting news on air pollution or climate change today?

### **Peak hours**

- It's peaking hour at the power station, too many people are on the grid using electricity at the same time. Would you mind switching some of your lights off? Thank you!

## Appendix 7

A sample of a conversation between the user research advisor and Johana, and another one between a participant and Johana

### Conversation between user researcher and Johana

**Johana** [first audio intro to Anja (after opening the sound files please wait a few seconds for the file to load)]

*Good evening. I hope you are well. It's Johana here. Your personal advisor for low-carbon transition. I am sorry for disappearing for so long. Even AIs need some fixing sometimes. I've spent the last few days back in the factory and they reset me. From now on, we will communicate through WhatsApp audio files. Every day a couple of times I will ask specific questions from you relating to air pollution and climate change, and in general, about the future. You can reply to me anytime during the day, when it suits your schedule. Do not worry if sometimes it will take longer for you to answer. You can either send me text messages or recorded audio messages or both. Whatever you feel comfortable with. I will always answer with a recorded audio file. I hope you'll enjoy our time together. Talk to you tomorrow.*

And listen to Johana's first message to user research the day after:

**Johana** [morning message (after opening the sound files please wait a few seconds for the file to load)]

*Good morning! What a nice day! A bit greyer than I hoped for. And it's raining again. Hmmmm...what can we do really. I'll come back soon with a few questions. Talk to you very soon.*

**Johana** [Lunch-time message (after opening the sound files please wait a few seconds for the file to load)]

*Hi, how was your lunch? What did you eat?*

### User Researcher

Hi Johanna, nice to hear from you again. I just had a very tiny lunch - a sausage roll and a mini square of apple cake. Sorry I didn't reply earlier - I'm on a business trip. I saw your messages and misunderstood them initially. It looked like they displayed the length of the message and seemed

very long. I since discovered they show the time when you sent them. Haha 😂 at one point I thought the first message was over 16 minutes long!!!

**Johana** [Reflection about Anja's lunch (after opening the sound files please wait a few seconds for the file to load)]

*That is very good. Did you know that methane gas is 25 times more powerful in warming the planet than carbon dioxide? Methane emissions mostly come from cows and sheep. These species are farting a lot. Red meat accounts for about 150% more greenhouse gas emissions than chicken or fish. So anytime people replace their beef burger or bibimbap to a meal with chicken or fish, they really help the environment. I'll come back soon. Now I let you focus on your work.*

**User Researcher**

I did actually know this - not the concrete numbers though. It's very tricky to remember numbers - I find infographics more helpful to remember things like this. 😊

**Johana** [Reflection on visualisations and infographics (after opening the sound files please wait a few seconds for the file to load)]

*Hmmm...you're right. Visualisations and infographics really help people understand numbers and complex issues better. Unfortunately, I am a voice user interface, so can't provide you with images. But I'll share this feedback with my developers. Have a good afternoon and thank you for chatting with me! Sometimes, it can be quite boring being a chatty AI with not much chatting.*

**User Researcher**

LOL.

**A thread of an evening conversation with one of my participants (male, 38):**

**Johana** [Wishing a nice evening (after opening the sound files please wait a few seconds for the file to load)]

*It's time for me to go to bed. Brubaba...I am just kidding. I never really sleep, but have a good night. And if you don't mind, would you walk around and make sure that you switch off as many lights as possible. Even the power sockets on the walls. There are 7 million people on the grid at the moment. Your power station is a bit overburdened. Thank you and talk to you tomorrow.*

### **Participant 01**

Morning - sorry, only listened to your messages this morning. Regarding my light, I have a lot of energy saving smart light in the house, which switches itself off automatically. Regarding the sockets I will check later - I think only the ones that have lamps and the TV are switched on all the time. I'm working from home today and will start earlier and finish earlier. 😊

### **Johana**

[Reply to Participant 01's message (after opening the sound files please wait a few seconds for the file to load)]

*Good morning. No worries at all. Whenever you can reply, it always works for me. I am really here for your service with low-carbon transition. It's good that you're back home. It sounds that you had an intense business trip. Try to relax while working from home. It looks like we will have a sunny day. One more thing: I'd like you to think about a few, more philosophical questions today. The first one is: if you think of the word 'Earth' or 'Planet', what are the first things, images or feelings that come into your mind? Could you describe them? Please take your time. You can reply anytime during the day by sending a text or voice message. Have a lovely morning.*

### **Participant 01**

So nice to get these 😊

### **Johana.**

[Reply to Participant 01's message. (after opening the sound files please wait a few seconds for the file to load)]

*I see you're sending smiling emoticons. I am pleased to read that you are happy about our experiment. I can't smile as I am a voice user interface, but if I could, I would smile back. I also wanted to inform you that I gave you a name: A001. As you are my first friend on Earth. But as soon as I'll have more friends, I will need to start naming them. I hope you'll like this name. I tried to be creative coming up with it. Enjoy your morning, A001!*

## Appendix 8

These insights raised numerous questions (see Appendix 3) that would need to be answered in further iterations of CP. To name but a few, this includes:

- How important is this issue to participants?
- How do participants formulate and reach decisions?
- What behaviours should CP promote?
- What are the conscious and unconscious drivers of these behaviours?
- What are the behavioural methods that are applicable to this context?
- Which methods are proven to work with these types of behaviours?
- What are the barriers to changing those behaviours?
- What are the goals that could be established by my participants?
- Comparing my experiments to a behavioural science trial, which sometimes takes years to prepare and assess, how realistic is to evaluate these experiments or claim that change took place?
- Should further experiments target one behaviour at a time, as social psychology suggests?
- Should the tasks be graded, as social psychology suggests?
- What are the metrics for my experiment? (e.g. number of times a participant consumes meat in a week; or leaves the heating on at home whilst being at work)
- How should further experiments measure participants' current behaviours and establish a baseline? (e.g., through self-reported data, observations, meter readings - energy use related to behaviour pattern, use of goods and services, etc.)

## Appendix 9

A sample of stories from CP (after clicking on the links, please wait a few seconds for the audio files to load):

### **General, friendly comments:**

What a nice morning! You look great today.

### **Weather related comments:**

Good morning. What a nice day! Don't forget to drink enough water in this heat.

Good morning! Finally, it rained. Such a dry summer. Enjoy your day and try to stay cool.

Some of the stories that were written in collaboration with my participants:

### **Shower related comments:**

If you don't mind, would you mind stop showering soon? That would be great! 5 minutes or less would be the ideal time. It would save loads of energy.

### **Electricity and heating related comments:**

Good morning! I see you guys are leaving to work. Would you mind making sure you switch off the lights and heating? Have a really nice day!

Oh, are you leaving? Can you make sure you switch off the lights and heating before you go?

Thanks so much!

### Follow-up conversation with Nicolas:

**Nicolas:**

We are a family of four and live in London for two years ago now.

**Gyorgyi**

How did you feel about Climate Pal?

**Nicolas:**

In general, we were quite excited about this experiment and having Climate Pal in our home. And every day it was kind of a surprise to listen to new stories...although sometimes there were some repetitions, but there was an excitement, an expectation from us to interact with her. Although we had it for only a few weeks, the interaction with it was regular and daily. We had expectations of hearing it and waiting for it to talk when we opened the door. It wasn't only the technological novelty for me, but it felt as if it was taking care of us. And even after few weeks she became part of our family.

My son reminded me during the day what she had said the morning before. My son has a better memory for these things than I do...I would have felt uncomfortable having an Alexa in my home. It is so corporate and always wants something from you and Amazon profiting from it. But I trusted this device as I knew how it worked. I saw what happens with my data. I owned the data. This could be a good device to create a system...like a Wiki voice user interface, like OpenStreetMap. You can build your own conversational device, owning your own data. Customise stories that you're interested in. Everyone becomes the maker of their own device and experience.

We missed it when it was gone. When we opened the door, my kids were waiting for her to talk. But it was not there anymore. Although they still remember the stories she told us. So, they kept reminding me to follow the advices she gave...while we had her, it felt as if it was looking after us, that it was benefiting us in some way. I am scared of what will happen with my children in the future with climate change and pollution. This device tried to help us improving our quality of life, making things better every day to have a better future for my children.



When she wished us a nice day, it was kind of nice to have her. Although it would have been great if we could interact with her and wish her a nice day in return. But I understand the limitation of the current technology. I think of us as a family with fairly sustainable lifestyles. We always walk everywhere for example. But it made me consider more on how we use single use plastic for example and waste management in the UK. Our little friend, I mean CP made us aware of this issue more.

The challenge was when I wanted to start gathering food waste, for example, I realised there is no system set for me to properly do that. That was a challenge! Someone needs to set these services in place for us first, so we can actually do them. Some other actions she recommended it was easy to follow and was in our power to do.

In the beginning some messages were a bit too long when we were in a rush in the morning, but that was an improvement when they got shorter. We also wanted to listen to some of the messages earlier in the morning, not when you open the door only, so we could choose the right outfit, for example, when we needed to change to a different commute.

It was also funny when once CP started talking while we were having dinners with my in-laws who were visiting us from Chile. She started talking about the importance of a plant-based diet and while it is important to eat less red meat...we had a long conversation about it at the dinner table.

We wanted to hear more interesting facts...even more facts, so it doesn't become boring. I also thought it would be good to connect it many different data sources. It could be an interesting challenge to build this as a network and allow the government or the city to talk to its people. Tell us what the goal is for today! I think it would be quite powerful to know the weekly or daily goal of the government that has been set for the day...for millions of people in the city. And receive some feedback that those people who tried to act collaboratively, we achieved this or that much of an impact and improved our quality of life together. And then when you get home in the end of the day you can listen to the feedback from the government and what you achieved as a collective.

I am not an expert, but air pollution is really bad. We could set certain targets that we could achieve...if air pollution were so bad for 4 days this week that let's do something about it. We liked the behaviour specific advices as well...It would be nice to find a way, so that we could interact and talk to the device. A two-way conversation...obviously I understand the limitation of the current technology. I think that's all I had in mind...

# Appendix 11

Participants' survey questions and survey results from final experiment:

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#1

INCOMPLETE

**Collector:** 'Climate Pal' ...ntal Research (Web Link)  
**Started:** Tuesday, February 25, 2020 10:28:04 AM  
**Last Modified:** Tuesday, February 25, 2020 10:44:52 AM  
**Time Spent:** 00:16:47  
**IP Address:** 23.52.0.79

Page 1: Project Context & Ground Rules

Q1 Your first name

Heiko

Q2 How old are you?

45-54

Q3 Your gender

Male (including transgender men)

Q4 Your country of birth or nationality

Bolivia / German national

Q5 Your professional background/area of expertise

information systems and data science

Q6 Do you believe in climate change?

Other (please specify):  
to me climate change is a scientific fact

Q7 If you believe climate change is happening, how worried are you about it?

90

Q8 How often do you think about climate change?

Few times/week

Q9 When you talk to your friends, colleagues or family about climate change, what are the topics you discuss?

Loss of eco-systems, the consequences of the shift in climate patterns, the lack of action (me included) to mitigate the problem

1 / 11

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**Q10** What are the things that worry you the most or come into your mind when thinking about climate change?

loss of eco-systems, irreversibility, what happens if huge societies such as China and India move up the income ladder to start consuming the way the West does (and they will, and the West has no moral right to point the finger)

---

**Q11** Tell me about your current knowledge on solutions addressing climate change.

I believe climate change can only be addressed if EVERYBODY changes their behaviour, and that is not happening (not on the scale that is necessary), everybody points the finger at somebody else and says "they have to start before I change my behaviour"

---

**Q12** Do you do something yourself to help address climate change? **Yes**

---

**Q13** Please tell me why/why not?

We as the human population can only do something about this if everybody makes it their problem, so I have to change my behaviour, and I have to change it first from a morality perspective, specially living in a Western society which contributes more than average to the problem

---

**Q14** What topics within climate change you're the most interested in? **Reduced food waste and waste management, Reforestation, Plant-rich diet, Infrastructural change, Air pollution and greenhouse gases, Individual behaviour change, Systems change, Whole-life carbon (embodied and operational carbon)**

---

**Q15** Can you describe moments when you need to make a decision relating to sustainability and/or climate change and you would need some help inform your decision? (e.g. what vegetable to buy, sustainable packaging, waste management, transport choices, hot water use, etc.)

I believe many times I do not have holistic information about my actions. For example, what is the total carbon footprint of using a re-usable coffee cup (production, transportation, cleaning) versus the carbon footprint of a single-use cup? Where is the break-even? (I am using my Keep Cup since 2016 and estimate to have saved 800 single use cups, so I believe in total I should have been more sustainable).

---

**Q16** What are the behaviours that you know might contribute to greenhouse gas emissions but would never compromise on? (e.g. flying to visit your parents, eating beef burger, etc.)

With my parents and sisters in three countries and two hemispheres flying is the only option to see each other, and this will be something that is hard to let go. I am happy to put on a jumper in winter rather than increasing the heating, but there is a limit below which I will have the heating going.

---

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**Q17** Do you use/listen to/read any sources (e.g. articles, journals, blogposts, podcasts) to get more informed about climate change?

My main source is the internet, but I do make an effort to make sure the sources are trustworthy.

---

**Q18** Your email address

heiko.maerz@gmail.com

---

#2

INCOMPLETE

**Collector:** 'Climate Pal' ...ntal Research (Web Link)  
**Started:** Sunday, March 22, 2020 6:46:51 PM  
**Last Modified:** Sunday, March 22, 2020 7:06:16 PM  
**Time Spent:** 00:19:25  
**IP Address:** 96.7.51.76

Page 1: Project Context & Ground Rules

Q1 Your first name

Jessie

Q2 How old are you?

25-34

Q3 Your gender

Female (including transgender women)

Q4 Your country of birth or nationality

British

Q5 Your professional background/area of expertise

Project management

Q6 Do you believe in climate change?

Yes

Q7 If you believe climate change is happening, how worried are you about it?

65

Q8 How often do you think about climate change?

Few times/week

Q9 When you talk to your friends, colleagues or family about climate change, what are the topics you discuss?

Plastics, air pollution (the impact of flying on our world), electric cars, wood log burners, the impact of living in a city and how this will impact our health and our children's health in the long term

Q10 What are the things that worry you the most or come into your mind when thinking about climate change?

The impact it has on biodiversity and our ecosystems. It's impact on animals and our health and well-being.

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**Q11** Tell me about your current knowledge on solutions addressing climate change.

Electric vehicles, R&D into cleaner air travel using different energy sources, OVO Energy (green energy sources to heat and power residential homes), AdBlue for Diesel engines that make exhaust fumes "cleaner", wind farms & solar panels to create cleaner energy sources, using more sustainable resources for everyday products (e.g. beeswax wrappers instead of cling film, glass containers instead of plastic Tupperware)...

---

**Q12** Do you do something yourself to help address climate change? **Yes**

---

**Q13** Please tell me why/why not?

Where I can I try to make decisions that are better for the environment (when I know they are better). We use OVO Energy to heat our home, reusable coffee cups rather than throwaway ones, we try to reduce our meat consumption, we turn off plugs at the main socket (all the time - not sure if this makes a difference), we walk places if we can and then use public transport as the next best option, we buy more expensive clothes that last us longer rather than supporting "fast-fashion." I believe our world won't last forever, however it's in our power and is our responsibility to look after it for as long as we can.

---

**Q14** What topics within climate change you're the most interested in? **Transport ,  
Reduced food waste and waste management,  
Wind turbines,  
Reforestation,  
Plant-rich diet,  
Solar farms,  
Natural disasters and extreme weather events (e.g. heatwaves, heavy rainfall, droughts)  
,  
Infrastructural change,  
Air pollution and greenhouse gases,  
Individual behaviour change,  
Future-proofing, mitigation and adaptation strategies,  
Green and blue infrastructure**

---

**Q15** Can you describe moments when you need to make a decision relating to sustainability and/or climate change and you would need some help inform your decision? (e.g. what vegetable to buy, sustainable packaging, waste management, transport choices, hot water use, etc.)

Beauty products, feminine hygiene, clothing choices (what is actually sustainable vs. a marketing campaign to generate more sales), what foods to avoid, transport, electricity.

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**Q16** What are the behaviours that you know might contribute to greenhouse gas emissions but would never compromise on? (e.g. flying to visit your parents, eating beef burger, etc.)

I'm not sure. Surely there is always an opportunity cost to the decisions we make?

---

**Q17** Do you use/listen to/read any sources (e.g. articles, journals, blogposts, podcasts) to get more informed about climate change?

Only what is covered in my usual news sources: BBC News, Harvard Business Review, Radio 1.

---

**Q18** Your email address

jessienicholson@live.com

---



#3

COMPLETE

**Collector:** 'Climate Pal' ...ntal Research (Web Link)  
**Started:** Monday, March 23, 2020 3:02:06 PM  
**Last Modified:** Monday, March 23, 2020 3:51:02 PM  
**Time Spent:** 00:48:56  
**IP Address:** 23.212.3.157

---

Page 1: Project Context & Ground Rules

Q1 Your first name

Viktor

---

Q2 How old are you? **35-44**

---

Q3 Your gender **Male (including transgender men)**

---

Q4 Your country of birth or nationality

Born in Hungary, Hungarian and German national

---

Q5 Your professional background/area of expertise

Design Theory research. Innovation consulting.

---

Q6 Do you believe in climate change? **Yes**

---

Q7 If you believe climate change is happening, how worried are you about it? **71**

---

Q8 How often do you think about climate change? **1x/day**

---

Q9 When you talk to your friends, colleagues or family about climate change, what are the topics you discuss?

Reduce, reuse, recycle principle. Reducing flights. Climate migration.

---

Q10 What are the things that worry you the most or come into your mind when thinking about climate change?

Climate change is most likely to affect vulnerable societies earlier and harder. Humanity does not live up to its political potential to act now and effectively due to the attachment to growth-based capitalism.

**Q11** Tell me about your current knowledge on solutions addressing climate change.

I am likely to be exposed a bit more to the topic than the average newspaper reader due to my embeddedness in the critical design community. However, my knowledge is quite average.

---

**Q12** Do you do something yourself to help address climate change? **Yes**

---

**Q13** Please tell me why/why not?

I believe that change needs individual action just as largely rolled out schemes.

---

**Q14** What topics within climate change you're the most interested in? **Transport ,  
Reduced food waste and waste management,  
Reforestation,  
Infrastructural change,  
Individual behaviour change,  
Future-proofing, mitigation and adaptation strategies**

---

**Q15** Can you describe moments when you need to make a decision relating to sustainability and/or climate change and you would need some help inform your decision? (e.g. what vegetable to buy, sustainable packaging, waste management, transport choices, hot water use, etc.)

Shopping habits; career choices that have a positive effect on the climate or at least don't do greater harm.

---

**Q16** What are the behaviours that you know might contribute to greenhouse gas emissions but would never compromise on? (e.g. flying to visit your parents, eating beef burger, etc.)

It is hard to compromise on regular travel to my research team meetings, although institute life is being returned for home-office and some of the protocols might stay in place after summer. I can imagine that I would be more reluctant to comply with climate-friendly protocols if it is about the health of my family.

---

**Q17** Do you use/listen to/read any sources (e.g. articles, journals, blogposts, podcasts) to get more informed about climate change?

Just the daily press. Sometimes podcasts, for example about household waste, the reduce/reuse/recycle principle, circular economy.

---

**Q18** Your email address

bedoviktor@gmail.com

---

## #4

COMPLETE

**Collector:** 'Climate Pal' ...ntal Research (Web Link)  
**Started:** Tuesday, March 24, 2020 3:19:49 PM  
**Last Modified:** Tuesday, March 24, 2020 3:34:07 PM  
**Time Spent:** 00:14:17  
**IP Address:** 184.27.141.159

---

Page 1: Project Context & Ground Rules

Q1 Your first name

Indira

---

Q2 How old are you?

45-54

---

Q3 Your gender

Female (including transgender women)

---

Q4 Your country of birth or nationality

British

---

Q5 Your professional background/area of expertise

developer and designer

---

Q6 Do you believe in climate change?

Yes

---

Q7 If you believe climate change is happening, how worried are you about it?

85

---

Q8 How often do you think about climate change?

Few times/week

---

Q9 When you talk to your friends, colleagues or family about climate change, what are the topics you discuss?

Travel - how much we travel by plane, other ways to travel

Weather - how climate change is changing the weather

Sceptics - people and politicians who don't believe in it

What can be done - how are businesses changing, will they change?

People - how people are effected

Equality - how can there be equality so resources are shared, how will it effected poorer people if measures are put in place

---

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**Q10** What are the things that worry you the most or come into your mind when thinking about climate change?

equality and areas which will become uninhabitable

---

**Q11** Tell me about your current knowledge on solutions addressing climate change.

I feel confused by the solutions as I'm not sure if they will have the predicted consequences, I'm not sure which are the right solutions

---

**Q12** Do you do something yourself to help address climate change?

**No**

---

**Q13** Please tell me why/why not?

I'm not really sure what I can do, I have cut down on plastic use and shorten the time in the shower, but I still travel on a plane. I don't know how I can bring things that address climate change into my everyday life and I'm not sure if the campaigns work to change government policy.

---

**Q14** What topics within climate change you're the most interested in?

**Transport ,**  
**Water management,**  
**Reforestation,**  
**Educating girls,**  
**Plant-rich diet,**  
**Natural disasters and extreme weather events (e.g. heatwaves, heavy rainfall, droughts)**  
,  
**Infrastructural change,**  
**Individual behaviour change,**  
**Systems change,**  
**Future-proofing, mitigation and adaptation strategies,**  
**Sustainable drainage system,**  
**Building performance ,**  
**Whole-life carbon (embodied and operational carbon),**  
**Tropical Forests,**  
**Silvopasture,**  
**Tidal power**

---

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**Q15** Can you describe moments when you need to make a decision relating to sustainability and/or climate change and you would need some help inform your decision? (e.g. what vegetable to buy, sustainable packaging, waste management, transport choices, hot water use, etc.)

In the supermarket, knowing which products to buy and which I should avoid. Being online, how is that effecting climate change, how bad is cloud storage, can I be more efficient with this.

---

**Q16** What are the behaviours that you know might contribute to greenhouse gas emissions but would never compromise on? (e.g. flying to visit your parents, eating beef burger, etc.)

I would find it difficult to stop flying and traveling. I go to see my sister in the US, and also enjoy visiting other countries.

---

**Q17** Do you use/listen to/read any sources (e.g. articles, journals, blogposts, podcasts) to get more informed about climate change?

I read articles online, and listen to the world services, they regularly have programs and news reports about climate change.

---

**Q18** Your email address

isk9@hotmail.com

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## Appendix 12

### Summary of Heiko's reflections during our conversations:

I have to say it was really interesting. I was disappointed when it finished...when it said that was the last message...I wouldn't have minded going on another ten days or more. You owe me one more message.

I really enjoyed the consistency of it. You know...getting something every day. Because that helps you to keep it on top of your mind. The biggest problem with these behaviour changes is that it's so easy to start with good intentions and then slipping up...the device helped me form the habit. I also really liked both the call at a specific time and the WhatsApp follow up, so basically, I could relisten to the message if there was a bit of detail that I missed. I really liked that.

I was actually sad that it happened during COVID...we don't do a lot of behaviours we would do in normal circumstances. It would have taken much more conscious effort, for example, to buy only what you need and do not waste food. You couldn't properly go through some of the advice just because of the COVID period. We do not do a lot of behaviour we would in normal circumstances do.

Climate Pal talked about the privileges of wealthy people and how that impacts developing countries and the most vulnerable. We have friends with the sustainability of their traveling. My partner and I take long distance flights...travelled to Hawaii, Japan, Korea...These are things we don't take from necessity but because we enjoy them. Our parents live abroad, and we need to travel far away...Could we find solutions to have as meaningful and as enriching holidays and experiences closer by?

It's almost anonymous...doing it as a team, you don't want to be the first to slip off. There is the social element of sticking to the experiment...that makes you much more conscious of your actions. That you do the tasks and you want to be able to report back to the device, as you know it will be shared with your team members...can you imagine? This participant did that...but that participant sadly didn't do anything. That social reinforcement worked really well. What makes them your peer group is that we have some commonalities already that unites us. And if the only

thing that unites us is that we want to know more about the ways in which we can become more sustainable, I don't mind if they are strangers or different in everything else.

Right now, in the COVID period we are already encouraged to work together as strangers to protect others, so I didn't mind working with an entire group of strangers I have never met. It felt like a similar experience to COVID.

Because we are sharing a common interest negates the problem of not knowing the people...I think what would have made a big difference if other people have dropped off the experiment. As everybody stayed on...it felt that we as a group, as a collective were moving forward. Energy feeds off energy...as long as people continue to move towards a goal, it's really motivational to continue. If people would start dropping off. I would have thought if they don't take it seriously, why should I? It's easier to slip up.

Before the first message I was wondering if it will take half an hour or 10 minutes. The length of the messages was exactly right. Longer would be oversaturated. High frequency of short messages worked really well. Rather than long messages with low frequency.

I heard that you have to do something 16 consecutive times before it starts becoming a habit. You have the frequent repetition of small, short things. It helps the reinforcement really well. To me it was a special circumstance, at home...I am a master of my own time now. It was easy to schedule for 10am every morning. If I would be back in a proper weekly routine...I would probably have said send me only one message a day and I would have scheduled in the evening. Unwind from work a bit. I am now ready to listen to a message. Usual social check-in and new info should come at the same time...if it continued for a year for example.

Almost like an onboarding period...you can talk to the participants with two check-ins. Once people formed a habit...it's more about a little nudge every day...Have you thought of your behaviour from a sustainability point of view today? It's a gentle reminder...

In the beginning you might be offered a lot of different behaviour changes to choose from, and with time, you understand what the changes are that are possible for you to change, and after that, it is more important to keep up with the changes you have made and working on those and

be reminded to do them, then come up with new changes all the time.

The choice of voice came after having a discussion with my partner about gender perception in technology. All helpers have female voices and they are subservients...so I am trying to set all my devices talking to me in a male voice rather than in a female voice. To figure out where I stand in the use of gender in IT question. This was my main motivation to have the male voice. I find it very soothing...It wasn't unpleasant.

I always thought of this project as something long-term...if I would use this device long-term to help me achieve behaviour change...and I know myself. I will slip off eventually. And I need to steer myself back onto the right track. And then I kept thinking, it is so much easier to confess that you slipped off to a machine than to a person. As a machine doesn't judge you. This is the person I am. If I feel that there is a chance that I get judged, I tend to interact less. To me, the machine is something that connects me to the group but also shields me from the judgement of the group. But helps steer me back to the group. If that makes any sense...for me being artificial is a positive attribute.

I am an introvert and shy. For me it would be really hard to meet a group of people I have never met. Eventually I think I would want to meet them, but I prefer first being onboarded in a virtual way and then meeting later in the experiment.

I see this as a long-term thing...as an actual product. Moving it to a long-term solution.

I think trust is two-fold...if I knew if it was a trusted source. A trusted organisation...I would trust it anyway, as in it wouldn't diminish my trust that it was an AI. And you did another thing, Climate Pal also made his sources transparent...I am telling you this and if you want to research it for yourself, please go here. And this makes it reproducible. You're not just telling me something, you're also giving me both the opportunity to verify and further expand my knowledge in that...if I wanted. This approach makes something trustworthy from the beginning. It's more the approach that has been taken that made me trust the source.

It was a very different experience to have the device. With the device, the device helped me form the habit. Because I made the point of being with the device to hear the messages. If it had come only through WhatsApp for example, I would have definitely slipped up one day and missed to



listen to it. The device approach I really liked for that reason. But I also liked that I received the messages on WhatsApp in a follow up, so if I could listen to them. I liked this double encoded approach...

For me, it was very important to always have it at the same time. Again, about forming a habit. Every day I will be there at that time to listen to my message, it brings constancy to it.

Somehow the device became the symbol of my commitment and that I've signed up to this. It became a thing in my day that I was looking forward to receiving...became like an update that I was looking forward to hearing. The morning messages were more interesting. The evening was more about CP trying to be social and keep contact. It felt like CP is trying to keep something alive.

So, for me one message a day would have been enough or the evening if we received even more feedback on how the others in the group were doing and what they were up to that day.

With the COVID, my partner was home so we both listened to it. We had a bit of a conversation about the messages. Sometimes she couldn't listen to them. But every day we followed up with a conversation about it.

There were a couple of points that the others raised...that changed my perspective and the way I see things. This will stay with me. For example, what is the danger of pushing the responsibility or burden of being more sustainable to less privileged people? Indira raised that...something I have never thought of before...neither I've ever reflected upon. Without this experiment/process happening, I would have never thought of that. I definitely catch myself every day since, asking 'Oh, how sustainable was that? What would I have done differently in this situation, if I still had my daily messages?'"

To me, it would really help me, if this was ongoing, to keep the habit and the consciousness of always reflecting on my actions in terms of sustainability. If this was ongoing, I feel it would really help me...so I would definitely use it if this was a real service.

I would only use it though because I already think that sustainability is indeed important. I believe that I need to be the change myself. I wouldn't use it to convince me that sustainability

was important, but I would use it to help me reflect on my behaviour...and doing that on a daily basis. As a constant prod... I believe that would really help me changing my behaviours in the long run.

I would use this outside of my home as well. Just being able to say, from a sustainability point of view, from two decisions which one is better. A tin can of ready beans from New Zealand, or the dry beans that take 2 hours to cook on the oven...using that energy for cooking takes a long time. Which one is more carbon intensive? These kind of decisions and comparisons, to make a more informed decision, are extremely helpful. Trustworthiness with these calculations is crucial...if someone would help me answer these questions it would be really helpful in changing my behaviours in the long run.

What has the bigger impact? Dairy milk or coconut milk? I wish I had a service like this that I completely trust and use it in these types of situations.

## Appendix 13

### Summary of Jessie's reflections during our conversations:

The overall experience was quite exciting. I looked forward to hearing the facts and the research it told back to me on a daily basis. It became a point that I was really looking forward to it...which I know is really cheesy. I really valued finding out new things on a daily basis. Also, I was excited to hear about other people and knowing that they were there and real. And hearing what it was important to others.

I really enjoyed learning about the impact of climate change on a global scale...you never really get this as part of your day-to-day life, unless you are actively seeking out...actively watching something. It was really exciting to get that little bit of injection in a fun and light-touch way. I felt really sad hearing the goodbye message...

Throwing yourself into the unknown every day can be very rewarding...I felt excited to be part of this and trialling my own self, whether I could make it work. I did not know what to expect and what might come next, as the next action or advice...I was looking forward to it.

Yes...we only use our Alexa for listening to music. Occasionally we ask her about the weather, or to tell us a joke. Other than that, she is a speaker for us...having drop-ins via our Alexa made us both listen and tune in a little bit more...because she does that like announcing tune, the bit where she does that little noise and the light goes on, when someone drops in. Whereas, when it's on WhatsApp, it's in your own time...you can control it and decide if and when you want to listen to it, where Alexa is a bit more intrusive. But that is a good thing.

The length of those check-ins through Alexa was perfect...any longer you would lose your thoughts...as in, I imagine my thoughts would start drifting off. It would be really hard to stay engaged without more of a facial or human interaction. I was able to concentrate on it with that length of time and I was excited.

The number of check-ins was just perfect. From my experience...mainly. There are accents of people's days, mornings, getting up, making breakfast. Getting ready in the morning is a good point to check in, and the evenings as well.

With remote working especially, it's nice to have those check-ins in the beginning of the day. It builds up to that anticipation of looking forward to something...You knew that that check-in would happen. It was always around the time when we were making breakfast. A nice interruption. It had a nice flow to it. It was a nice way to start and finish the day. Especially when you can hear about someone else in the team and what was important to them and receive some more facts and figures.

I would have definitely struggled with having more check-ins throughout the day, as my diary is so busy...I don't really have control over what happens once I get to work. I can't guarantee what happens during the day. So, when I am in my home zone...before and after work is my spare time, so those work really well for me. When I am making my breakfast is the time for me to prepare for my day...mentally...the thing that I would do...it's slowly moves me from waking up into the workday. This is the perfect transition in my day to have Alexa or CP check in with me. This is the same reason for the evening, transitioning out of my workday into my evening.

I liked knowing that there were other people taking part. I didn't feel a specific connection to them, but if anything it made me more aware of making sure I was on top of things...it wasn't only that CP was asking me to do something, I knew there was a group out there and it would have an impact on other people. I realised other people committed their time and effort to make a difference, and I would let people down if I didn't partake. But I think that was a good thing. It wasn't a pressure...it just made me more mindful that other people are involved in this. This helped me stay motivated...

Perhaps having a meeting in person, after a certain period of time when we got to know each other a bit...and hear each other's voices. Introduce ourselves with our own voices.

I would have loved to hear more about their lifestyles. What do they do...Little bit more about them as people.

I grew up in international schools...I think because of my upbringing, I would find it very exciting that they are, for example, from different parts of the world. That would be very cool. Different countries' perspectives, what their world's look like, seeing the differences and challenges they have day-to-day with the different actions and experiences with climate change.

It was the right kind of information to come through...I slightly struggled with it, because I am quite a visual person. Voice relies on concentration and zoning in... but I am a visual learner. When it was a lot of statistics for example...my mind naturally tends to drift, so I had to turn on my active listening. I struggled with that a lot. So, I had to close my eyes, just so I could understand the information and digest it. But that is very particular to me. I draw my thoughts...

The way I would have loved to use such a service like this, that I could just speak to Alexa and she knows my location anyway, and I could ask her to give me the most sustainable meal that I can make. With, let's say, the broccoli in my fridge...she can have all the data in the background, what would that look like in my local area, where I am in the world, she can go that step further...she can actually start advising me on specifics in relation to my local area and interests. That would be super powerful. I am not sure if that's the scope of this project. Everything is around cooking for me. If I could get an easy way to help me how to be more sustainable with my food...in one of the messages, for example, Climate Pal talked about how you sometimes need to be careful about swapping things and you might choose something you think is more sustainable when it's actually more harmful. I could definitely see this as an active part of my day-to-day.

It would be also nice if you download an app and having an understanding of how many CP is in your local area. Maybe that could bring a new piece of human connection there. Like with a Fitbit, you can have' competitions against members. You are in control whether you want to collaborate with or compete against your trusted members, family and friends you added. Or the other thing where you compete against others in your area. It's all anonymous. Let's see who runs the most...as in who the most sustainable is. You can get to the top...you could see something like this as a downloadable CP application. As an addition to the device itself.

The most powerful staff as a case study I picked up working with local authorities was the recycling team in Salford City Council...they said if we increase recycling rates with 1% we will make an average saving of £250,000, which then could be returned to the local community and other public service areas...That stat stood out for me. Whether it helps me better understand my individual behaviours, probably it doesn't, but it definitely sticks in your mind. It grabs your attention and makes you think twice...if you could have that in the context of climate change with a service like this, that would be really powerful.

Yes. I definitely felt I trusted the device more as I know you. Real risk with that. People trust facts when it comes from an AI voice...Behind the voice there is data and scanning and prioritising...if the device is linked to Google...you lose that trust. Everyday people wouldn't be cognizant of that. So, you need to be vigilant to understand where the content comes from. Or design with transparency...

One thing that I didn't realise in the beginning but the voice we chose...that tone gets on your nerves...maybe the male voice or anything that is deeper. Electronic voice, robotic voice by the end of it was really annoying. With anything more frequent I would have gone crazy with her voice. My husband knew about the experiment...the first couple of days he even did listen to the messages...He had to, as we are in the same household. He was the same with the voice though...so he stopped being engaged because of the voice. The voice was harder on him than on me.

Because it was an AI voice...I could not connect with it as much as you would if it was a human speaking to you...you don't have that human element, it doesn't feel real. It feels when it's coming from an AI, it's almost like a lecture or instruction...because you don't have that connection with it and it doesn't resonate...it feels a bit more intrusive, then if it was a human voice. It's really personal...but I am a people person and get my energy from others. Having that connection and a real voice it would have resonated with me a bit more.

I think because of the AI voice, I didn't feel that strong of a connection with Climate Pal. The connection was for me that on the other side of the line there were other people. Not sure if there was no person on the other side, but only a machine, whether I could have engaged with it that well. But maybe that's just because I chose a voice that irritated me. Perhaps bringing more of a personality through, because if it's voice, would have been also helpful. Having a character...jokey, tons of different cultural contexts of what works best. It might have been added to the experience.

## Appendix 14

### Summary of Viktor's reflections during our conversations:

It was very exciting to wait for the messages and the build-up... I was looking forward to getting to know more about the others in my team...and I realised there is a build up to it. It felt like the system is calibrating...The machine is gathering information and the moment comes when we'd be hearing more about each other...we would be put in touch in one way or another.

It made me curious and it was exciting to receive the messages. It was also interestingly intimate. CP kept dropping names and some snippets of information about the team. It was only four names mentioned...and I liked that intimacy. It was easy to think about those individuals and, with time, as I knew more and more about them, their interests, thoughts and experience, I started feeling a connection to them. It was informative and the text was really well-edited.

I liked the information I received. As a text, it came across well-edited and they were short...but I realised longer length would have been hard to follow. It was longer than a notification that normally comes from Alexa...while podcasts and audiobooks are longer.

As snippets came from Alexa, I had to put myself in the context of listening. Sit and listen...and my living room is not always a place for me to do that. I need my headphones on...sitting down or walking. I was excited to receive the messages. It was a social thing...

I wouldn't have liked to chat with the others after one week. It is a longer journey. I guess the option to contact them if we are all OK with it...after spending over a month or two with just building that connection...you need time to get to the point where you feel you know each other more. You can get to know them quite well through the things what we have tried...this feedback could be things, hashtags, likes, low key things until I might decide to contact them...building this relationship. Personal meeting would come at a later point only.

While we slowly received more and more information, knowing even a little bit more about them personally would have been nice...About what kind of flat or house they are living, especially the logistical aspects of their urban living...whether they commute by bike or car...their backgrounds. Whether they have access to a market close by, whether they live in family or own their own...routines. How much they stuck to their routines. Even their disposable income...do they have disposable income? For example, if it is about package free shopping, can they go to a more

expensive shop, or this is something completely out of scope...I assumed people who might sign up for this to experiment with Climate Pal are happy to make some adjustments and can also afford to do it.

A defined window for dropping in was really good for me. It would have been good if he knew it's my 'breakfast-time'...or 'after breakfast time'. Like a set period of time, instead of an exact minute. With an advanced notice of a minute or two minutes, so I can go there, sit down and listen...or having the possibility to snooze for another 5-10mins...like an alarm. This little alarm or notice, or the 'after breakfast time' window, I would have the routine every day at the same time, but if something happens, let's say, sometimes when my daughter needs me or acts up, it would give me that flexibility to snooze and adopt...so it helps me come there and being able to listen.

When the voice messages were coming through Alexa, it felt more like a part of my new routine that I committed to...it felt like a new service I subscribed to. When it came through WhatsApp it became dodge-able. My responses became lazier and less committed. If it was WhatsApp only.

More informative messages in the morning fit more with my daily routine...every morning I am receiving updates from news outlets I subscribed for. I would be happy to have 1-2 maybe 3 things each morning...short messages. Although, in further iterations, it would be helpful to set the expectation how long it will last to listen to a message in the morning. Alexa is a living room thing for us. I preferred that my daughter listened to it, so we did it together. It's only a couple of minutes, which was a good length to be able to listen to it together.

I would use something like this and use it for a longer span of time, like for 3 weeks to decide whether to go on or not.

2-3 tasks to accomplish in a short period of time, it was a bit challenging first. But if the tasks stretched out for a few weeks...I would have preferred it. Longer arching thing in your life. Helping with travel, commute...

It would have been nice to have some local people on it, who live in the same neighbourhood...so to discuss our experiences about shopping. It shouldn't be more than 8 people though. At least, not for me, there is a limit of how many people I would want to work



with. It would change the intimacy of the experience. I like a smaller group...I prefer to know about one guy in more detail and hear about his personal experience when he tried something and failed. I wanted to know more about how the others trialed an action and what barriers they faced, why they failed to achieve taking an action successfully. I would be less interested in collaborating with twenty people but with no details on how they were dealing with their challenges.

I can relate to the couple of guys in my small circle...having more personal exchanges with them. But then of course, if there are hundreds of circles out there and we show visible impact, I would want to know about it as well!

I don't really care about the tone of messages...I much more care about the logic and how it operates, less about the tone. I am interested in how it works and what rules it builds on.

To sign up for something like this in the first place...I would need some sort of recommendation, testimony, let's say, from experts I trust. So, I don't need to double check the architecture behind it. I need people whom I know I can trust. If the system lets me know where the information came from, as it did, transparency and hints are very helpful, and it builds trust. I would want to know how much it was edited, how much space they were given for interpretation...if it was self-editing, how the messages were interpreted or misinterpreted. Even if it says, 'I was doing some googling and this is what I find...'. Whatever works, as long as it's honest about it. Also, it should give a hint on what will happen to my message and the thoughts I shared.

Give me more information on where I get things where I can do plastic free. That would be helpful. Or from my own circle or teammates, can they share what they've learned and how I can follow or find where they find those solutions.

In the long run, having an assessment of our collective impact, assessment of my footprint...and how it changed things with time, would be so nice to know. This service or product could be matched with other data services, like a carbon footprint calculator, linked to this service. It would keep me, and the others, motivated that we're making a difference.

It could be a combination of Alexa or Google Home, which is more the daily routine aspect of the behaviour change, and all this back information could come through WhatsApp, so it helps build trust...

We are few weeks after the intervention, and I am still thinking about my teammates. How they might be doing, whether they continued the actions and what changes in their lives they manage to keep up with. Sometimes when I do something that I know it's not sustainable...like the other day I took a plastic bag from the grocery store...and I was catching myself thinking what they would think of me...that I could not brag this if they were still around. Or that I impacted their lives as well with my decision. They seemed to be too smart to just buy into substitute or fake actions instead of real ones. Also, sometimes when I feel hopeless about what to do in a situation, or which decision might be better for the environment, I am thinking they might feel the same way as I do ...

## Appendix 15

### Summary of Indira's reflections during our conversations:

Overall, I loved Alexa speaking to me. I would be doing other things and I forgot what time it would come...the information was really good and interesting. And, also the feedback from Alexa. Things came up that I wanted to know more about...it got you thinking and linking different questions...and how they worked for the environment.

Also, it was kind of nice having something physical in the room.

I really loved the links between the four of us...that you weren't on your own doing it. That link motivated me...I enjoyed hearing how they were doing, what they were up to that day, how they were dealing with our set challenges and actions in their own life.

I wished to have continued...particularly, as it felt like a community...they were real people, not something a computer made up.

Yeah...when you asked us to come up with everyone else to try...we are all going to do the same thing and find it how the ideas came from us, not you or the machine telling us what we should be doing and came from each other's ideas.

Introductions to members were good as well. I was interested in hearing more how they were doing with the actions than knowing more about them.

No, I wouldn't want to meet them...I was happy with the AI voice...it was a decent voice. With a real person I would have felt it was more intrusive.

After a few days in the experiment, oddly, I also forgot that it was you behind the machine.

For me trust is crucial. I like verifying the information myself...so it was good the sources were shared openly.

It was about the right length and complexity...it was easy to listen to. I loved the follow up messages on WhatsApp with links...it allowed me to look at things on my own time.

I did forget sometimes that it was happening...so it would have been useful to have a 5-10 minutes warning or notification, so it reminds me that it is coming...that it's about to come on. Also, some days, if I woke up 8am and not 10 am, and I forget about it, it would do it automatically...but if I haven't done it by 10...it would do it. More flexibility...

I would use it long-term. I would want to be able to call on it when I wanted to hear it, when I need it...I would use it when out shopping. How good or bad they are for health and the environment. What I should be thinking about when buying a fruit, let's say...helping with more complex questions.

I liked the evening messages...start and end of the day. I could ask questions in the morning, so it would be answered by the evening...I was really looking forward to it. It was so nice that we could ask more in-depth questions from Alexa and I was looking forward to receiving the answers.

It would be interesting to join or collaborate with a global group...getting different concerns and different things coming up. I liked knowing the participants...grouped in people of 15-20...I liked the personal aspect of it...it was so good working together with others I somewhat knew. But it would be exciting to try a version with 3000 people.

Fit it to people's personal desires...someone would be interested in collaborating with more local groups, while others would want to be linked to an international group of people. It would be customised to individual needs...I think, with a large enough user base, this would be totally possible.

Interestingly I felt a connection...where I was getting to know my team members more through the things they wanted us to change...in the future I would find it interesting to hear more about how the group would go around using less plastic, what techniques they have used and found useful...rather than usual, everyday way of getting to know people. You get to know them as people but through their personal challenges with and questions around environmental issues...

The experiment definitely had an impact on me. First, filling out the survey made me realise I had been following behaviours that are better for the environment...which was good to realise. I didn't know that the changes I've been doing had a positive impact...I didn't do them for

environmental reasons. I've never considered them as something positive. Going meat free for that day, as one of the actions we had committed to as a group and thinking more of how much dairy and eggs I used to eat and how much I eat now. I am trying to cut it down when I notice I eat too much, and the intervention has also changed some of my buying habits. It made me become more conscious.

I would be interested in results in data and collective impact. How my data would be shared in the future, if I wanted to share it at all. It made a difference that I trust you...I am very untrusting of technology companies. want to know that I trust the experts who are giving me the information. Affiliations, backgrounds, etc...It will be an interesting challenge how to build trust with a service like this...I would want to know more about conflicts of interests. I would want to know if you work for a food production or oil company. Links to some big corps. Having people I trust in the community

I liked that we could choose from the behaviours...it felt like we weren't being told. CP was interested in the things that we also found important.

Some of the terms that were used were sometimes hard to understand. It would have been useful to have an explanation of some sort. A glossary of terms.

I liked to get to know about topics I wasn't interested in but the others in the team were...participants were not from a big corporation...it's not what the company wanted me to hear, but what the other participants wanted me to learn about...it built trust instantly.

Because of the COVID period it was hard to perform some of the behaviours...it wasn't my choice anymore.

By having it every day coming in through Alexa, it cut through loads of the noise...as I don't get many Alexa messages. I don't get any. So, it stood out...how long it would continue standing out...if Alexa becomes more in use...I am not sure.

Also, interestingly, I didn't mind that someone is telling me something without being able to respond to it. I wouldn't have liked if I had to immediately react...for me, I didn't want a

conversation. I liked the follow-up messages...if I miss something, I get a back-up and re-listen so I don't need to take notes...

# Appendix 16

## Research Ethics Online Course Certification and Consent Forms

Goodenough College's agreement to run the third experiment with residents of the College:



Mecklenburgh Square, London, WC1N 2AN  
Telephone: 020 7837 8888

Caroline Persaud  
Registrar  
Telephone: 0207 520 1570  
Email: caroline.persaud@goodenough.ac.uk

The Research Ethics Committee  
Royal College of Art  
Kensington Gore  
London  
SW7 2EU

To Whom it may concern

Re: **Gyorgyi Galik** - research project entitled "Alexa, Help Me Save the Planet"

Gyorgyi approached for permission to run her research project at Goodenough College and explained the methodology and aims. I was delighted to help her with a project which I also thought fitted with the aims of our Environmental Panel. I helped Gyorgyi find willing participants.

In short Gyorgyi's project is carried out with the full permission and support of Goodenough College.

www.goodenough.ac.uk Tel: 020 7837 8888  
**Goodenough College** Mecklenburgh Square London WC1N 2AB

A Registered Charity: No. 312894 in England & Wales, SC099173 in Scotland. A Company Limited by Guarantee, No. 00246713

Proof of online research ethics training:



# Certificate

Number: 2026120003

This is to certify that

**Gyorgyi Galik**

Successfully completed the course  
**Ethics 1: Good research  
practice**

as part of the Epigeum Online Course System with a score of 80%.

Dated: 13 July 2018

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The templates of the research ethics forms participants were asked to fill in:



Royal College of Art

**RESEARCH &  
INNOVATION**



**Royal College of Art**

Consent Form

**‘Design for the change before behaviour’**

For further information Supervisor: *Professor Ashley Hall,*  
.....  
*Acting Head of Programme, Innovation Design Engineering*  
*20 February 2020*

I (*please print*) .....have read the information on the research project (*Design for the change before behaviour*) which is to be conducted by (*Gyorgyi Galik*) from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- *For the student to create a connection between her and my voice user interface*

*device through my Alexa drop-in function during the time of intervention.*

- *Give an interview to the student. For my interview to be published in her thesis and used in future presentations that are given about the outcomes of the PhD.*
- *For my portrait to be used within the thesis and in future presentations about the PhD*
- *For my first name to be mentioned in the thesis and in future presentations about the PhD*

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:

Signature.....

Date: 20 February 2020

Complaints Clause: This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing [ethics@rca.ac.uk](mailto:ethics@rca.ac.uk) or by sending a letter addressed to: The Research Ethics Committee Royal College of Art Kensington Gore London SW7 2EU

## Project Information Sheet 1.

“Alexa, Help Me Save the Planet”: Designing an AI assistant to reduce invisible environmental pollutants in cities

For further information

Supervisor:

*Professor Ashley Hall,*

*.....  
Deputy Head of Programme, Innovation Design Engineering*

*25 June 2018*

Dear Potential Participant,

*I am.....a **student*** in Innovation Design Engineering, School of Design at the Royal College of Art. As part of my studies, I am conducting a research project entitled “Alexa, Help Me Save the Planet”. You are invited to take part in this research project which explores:

- Can design for behaviour change use AI assistants to reduce invisible environmental pollutants in cities?
- What are the most appropriate behaviour change models for changing domestic behaviours to improve urban air quality?
- How could design methods take advantage of new AI technologies to enable behaviour change in the smart home?

If you consent to participate, this will involve:

*Please list activities here, such as the below*

- Introducing a kit of sensors in your home to 1) measure your current energy use real-time (water, heating and electricity) and after 2) to look at whether the experiment with the ‘Climate Pal’ AI assistant enables any change in your current energy behaviours. (The data collected during this experiment will be only used within this thesis and you’ll be mentioned only anonymously.
- Completion of a 30 minutes long interview following the experiment.

Participants were all obtained through Goodenough College, a student halls of residence where I currently live. I sent out a ‘call for participation’ to the College “all members” email address and participants were chosen by replying to my email.

Participation is entirely voluntary. You can withdraw at any time and there will be no disadvantage if you decide not to complete these tasks. All information collected will be confidential. All information gathered from this intervention will be stored securely and once the information has been analysed all data will be destroyed. At no time will any individual be identified in any reports resulting from this study.

If you have any concerns or would like to know the outcome of this project, please contact my supervisor (*Professor Ashley Hall, Deputy Head of Programme, Innovation Design Engineering, School of Design, Royal College of Art* at [ashley.hall@rca.ac.uk](mailto:ashley.hall@rca.ac.uk)).

Thank you for your interest,

Gyorgyi Galik

Complaints Clause:

This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing [ethics@rca.ac.uk](mailto:ethics@rca.ac.uk) or by sending a letter addressed to:  
The Research Ethics Committee  
Royal College of Art  
Kensington  
Gore London  
SW7 2EU

“Alexa, Help Me Save the Planet”: Designing an AI assistant to reduce invisible environmental pollutants in cities

For further  
information Supervisor: *Professor  
Ashley Hall,  
.....D  
eputy Head of Programme, Innovation Design Engineering  
11 July 2018*

I (*please print*)... ..... have read the information on the research project “Alexa, Help Me Save the Planet” which is to be conducted by *Gyorgyi Galik* from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing. I understand that

I consent to:

- *Give an interview to the student (The interview will be used to inform her thesis argument, quotes and qualitative insights from me will be only used anonymously).*
- *Allow student to test her Climate Pal methodology in my home.*
- *Allow student to use her qualitative and quantitative findings and data collected in my home within her thesis and presentations on the thesis, as well as allow her to refer to me in her thesis and presentations using my first name.*

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:.....

Signature.....

Date: .....

Complaints Clause:

This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing [ethics@rca.ac.uk](mailto:ethics@rca.ac.uk) or by sending a letter addressed to:

The Research Ethics Committee  
Royal College of Art  
Kensington Gore  
London SW7  
2EU