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Self-portraits of Personal Exposure to Air Pollution: On Where and When People are Exposed, and on Why it is Difficult to Avoid

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Self-portraits of Personal Exposure to Air Pollution:

On Where and When People are Exposed, and on Why it is Difficult to Avoid

Nicola da Schio

Abstract

I discuss personal exposure to air pollution through an analysis of the space-time trajectories of seven Brussels residents. Through an activity-based model, I examine how much, when, and where the subjects are exposed to $PM_{2.5}$ during a typical week. Drawing on social theories of practice, I explore why people become exposed by examining the role of perception and representations of air pollution in organizing a typical week and in considering alternative options. By framing personal exposure as a consequence of the enactment and synchronization of social practices, this research sheds light on how social and ecological processes such as urban planning, energy production, and weather intermingle with the lived experience of individuals and communities to produce specific patterns of pollution exposure. This article is the outcome of a citizen science project conducted in Brussels to test alternative approaches to measure and address outdoor air pollution.

Keywords:

air pollution; space-time trajectory; social practices; citizen science; Brussels

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Résumé

J'étudie l'exposition individuelle à la pollution de l'air à travers une analyse des trajectoires spatio-temporelles de sept Bruxellois(es). Grâce à un modèle basé sur les activités, j'examine dans quelle mesure, à quels moments et à quels endroits ces personnes sont exposées aux PM2.5 pendant une semaine type. En m'appuyant sur les théories sociales de la pratique, j'explore les raisons pour lesquelles les individus sont exposés à la pollution de l'air ainsi que le rôle que joue leur perception de la pollution dans l'organisation de leurs activités quotidiennes. En considérant l'exposition personnelle comme une conséquence de la mise en place et de la synchronisation des pratiques sociales, cette recherche met en lumière comment les processus sociaux et écologiques tels que l'urbanisme, la production d'énergie et la météo se mêlent à l'expérience vécue des individus et des communautés pour produire des configurations spécifiques d'exposition à la pollution. Cet article est. le résultat d'un projet de science citoyenne mené à Bruxelles ayant pour but de tester des approches alternatives pour mesurer et traiter la pollution de l'air extérieur.

Mots-clés

pollution de l'air ; trajectoire spatio-temporelle ; pratiques sociales ; science citoyenne ; Bruxelles

Introduction

A focus on human exposure to air pollution offers opportunities to explore what is probably the most frequent form of interaction between people and their environment: as opposed to contaminant concentrations, exposure requires the simultaneous presence of the contaminant and of a person at a given place and time. I take a people-centered approach to personal exposure through a focus on its key geographical and sociological dimensions, often overlooked by air pollution research: individual trajectories in space and time, and their sociological explanation.

Although they have their merits, air pollution maps offer limited information about people's actual exposure levels as they only provide average pollution concentration levels at home addresses. While these values say something about exposure, there are many circumstances that can exacerbate or counterbalance a given concentration level. In addition to the physical characteristics of a residence, such as the ventilation system and the distance from the road (Tong *et al*. 2016; Zhu *et al.* 2005), an individual's exposure is heavily influenced by their time geography, including when and how long they are at home, their modes of transport modes, the length, timing, and itinerary of their journeys, the pollution level in their working environment, and how and where they spend their free time; not to mention their socio-demographic characteristics and the resulting different levels of vulnerability (Dons *et al*. 2011; Int Panis 2010; Steinle *et al.* 2013).

Moreover, to fully understand personal exposure, in addition to monitoring pollution levels *where* people are and *when* they are there it is also necessary to know *why* people perform a given activity in a given place at a given time and how this affects their capacity to make use of alternative options that could reduce exposure. Simply measuring the level of exposure in a predetermined set of activities risks overlooking the inherent complexity of daily routines and differences that exist throughout society. There is no menu of activities and locations with different pollution "prices" that people pick and combine to design their typical week. The patterning of daily lives results from the bundling in space and time of multiple activities that are a product of a complex agglomeration of elements in a dynamic relationship with one another, including cultural conventions, expectations, shared meanings, material and immaterial infrastructures, and personal skills (Blue *et al.* 2016; Maller 2015).

This research aims to fill these gaps through providing a comprehensive account of personal exposure in people's daily life. To achieve this general objective, I pursue three complementary lines of inquiry:

- *How much, when, and where are Brussels residents exposed to PM2.5 during a typical week?*
- *How do they "sense" pollution? What are the hotspots in people's perception of pollution?*
- *How do and can they organize the space-time trajectories of their typical week accordingly?*

By framing personal exposure as a consequence of the enactment, organization, and synchronization of social practices I highlight how social and ecological processes (such as urban planning, energy production, and weather) intermingle with the lived experience of individuals and communities to produce specific patterns of exposure. This allows us to go beyond a focus on places as the target of air pollution analysis to a focus on people and the different extents to which they are exposed to pollution, perceive it, and have the capacity to avoid it.

This research is the outcome of a citizen science project in Brussels in the context of a broad mobilization for cleaner air. The 'citizens' whose "exposure portraits" I present here were involved in the design and development of the investigation and in the collection of the data. This approach not only allowed gathering a great deal of local knowledge and a comprehensive understanding of people's routines and motivations, but also assists in formulation of a powerful message to those who are actually exposed to air pollution, and emphasizes the societal value of air pollution knowledge. Since the current measures, maps, and communications on air pollution appear inadequate to address the public health dimension, it seemed appropriate that this project should test a radically different approach, including in terms of its epistemological basis.

I first discuss the relevant literature, specifically concerning activity-based exposure monitoring, social practice, and citizen science, and how they intersect and contribute conceptually and methodologically to the definition of the research. I then describe the Brussels context and indicate what knowledge gaps I aim to fill. I next discuss the different aspects of the methodology and the implications and trade-offs that the project faced when navigating between various disciplinary traditions, followed by a description of the three main activities that make up a person's typical week, an analysis of the results of the pollution monitoring campaign, and a sociological analysis. I conclude with a consideration of how the results from this research contribute to a better understanding of personal exposure and of social and environmental practices.

Activity-Based Monitoring of Personal Exposure to Pollution

Air pollution is the single largest environmental health risk in Europe (EEA 2018; Lim *et al.* 2012). It has been found to be related to premature death due to stroke, cancer, and circulatory and lung diseases (WHO 2014). Different studies have also found it to have adverse effects on cognitive development, fertility, and pregnancy, and to be associated with forms of diabetes, obesity, systemic inflammation, ageing, Alzheimer's disease, and dementia (EEA 2017 and references therein). While pollution is a wide-ranging socio-ecological phenomenon, it only becomes a problem for human health when people are exposed to it. Personal exposure, in particular, has been defined as "any contact between an airborne contaminant and a surface of the human body" (Sexton and Ryan 1988:208).

Assessments of personal exposure estimate the magnitude, duration, and frequency of exposure to a contaminant in a variety of ways. Activity-based monitoring methods are designed to combine information about individual space-time trajectories with data about pollution levels at the specific location, time, and microenvironment in which a given individual happens to be (Int Panis 2010; Steinle *et al.* 2013). These methods involve either direct monitoring – using portable samplers and a record of activities, schedules, and locations–or indirect monitoring, performed by combining space-time logs with high-resolution pollution data modeled on recordings from fixed stations. Activity-based methods tend to provide a more accurate picture of actual exposure than estimates based on presumed static population distribution (see Dewulf *et al*. 2016; Dons *et al.* 2011). In 2019, a European Parliament resolution on clean air also called for measurement strategies that take into account individuals' time and space trajectories (European Parliament 2019).

The various activities and microenvironments that make up a person's space-time trajectory are often condensed into broad categories, such as home time, transport, or work, each presenting different exposure level. For example, a study focusing on the exposure to black carbon of 62 residents in Belgium found the category "home" to contribute 51.7% of the total exposure burden (vs. 65.7% of total time use), "work" 12.2% (vs. 17% of time use), and "transport" 21% (vs. 6.3% of time use) (Dons *et al*. 2012). Similarly, a study involving nearly 300 volunteers in the Brussels-Capital Region found that workplaces, homes, and other indoor spaces offered the lowest average levels of exposure, followed by green spaces, other outdoor spaces, and transport (Bruxelles Environnement 2017). A particularly fertile branch of research focuses on the levels of exposure characterizing different transport modes (for a Brussels based study, see Int Panis *et al*. 2010; for a recent literature review, see de Nazelle *et al.* 2017).

Social Practices and Space-Time Trajectories

Although activity-based models can provide detailed information about when and where people are exposed, examining the determinants of individual space-time trajectories and the different meanings, explanations, and experiences that people have for different activities is also critical to obtain a better understanding of how environment intersects with behavior. While there are many ways to shed light on these issues, the citizen science project builds particularly on research that conceptualizes social life as the reproduction of social practices, defined as "habitual ways of acting that have just come to feel appropriate within particular contexts as a result of the objectives typically associated with being within them and the physical conditions from which they are made up" (Hitchings 2011:2841).

A social practices ontology is particularly relevant as a focus on practices as units of analysis rather than individuals and their psychology. The constitutive elements of social practices include materials (such as objects, tools, and infrastructures), individual competences, know-how, and knowledge, and the meaning of a practice, deriving from past experience and its social significance (Shove *et al.* 2012). Social practices rarely exist in isolation but are characterized by patterns of competition and interdependency. Whether and how individuals perform a certain practice is often dependent on how they organize in space and time the multiple practices that make up their routine, and on the intersection with other people's practices (Maller 2015).

Thus, human action and change are rarely the straightforward expression of personal preference or of rational and *ex ante* deliberation, but result from the concurrent presence and entanglement of different elements (that is, competences, materials, and meanings) that are distributed unevenly among individuals (Blue *et al*. 2016). Exploring the nature and the implications of such differences is not only important to understand why people perform different social practices and combine them into their daily life; it is also critical to understand people's capabilities and opportunities to change. As Walker (2014:52) writes: "if a potential practitioner lacks the capabilities required to perform a practice (and through that achieve related functionings) they are 'un-recruitable' and excluded (at that point in time) from reproducing the practice–however willing they might be, and however actively the practice might seek to capture them" (see also Walker 2013).

The notion of social practice has been used in different contexts at the interface between healthy lifestyles (Blue *et al*. 2016; Hitchings and Latham 2017; Maller 2015) and sustainability (Hitchings 2011; Latham and Wood 2015; Middleton 2011; Shove and Spurling 2013; Strengers and Maller 2014). It also shows potential for investigating personal exposure to air pollution (see also Hodgson and Hitchings 2018). I obviously do not refer to "breathing toxic air" as a social practice in the same way others refer to smoking, cycling, or consuming organic food. In this context, the project's understanding of personal exposure in different micro-environments and throughout an individual's space-time trajectory is as a consequence of the enactment and coordination of different social practices, which we try to unravel. Vulnerability to the impacts of air pollution can also be a factor that potentially prevents people from engaging in certain practices.

Citizen Science

The third stream of research focuses on citizen science as a methodology and as an object of research. Broadly speaking, the expression refers to different forms of undertakings where "non-professional scientists voluntarily participate in data collection, analysis and dissemination of a scientific project" (Haklay 2013:106) . Though citizen science methods are used in a variety of disciplines, a large part of published research comes from the field of ecology (Sorensen and Jordan 2016).

Citizen science is celebrated by those who practice it for its potential of bringing communities and science closer together to address knowledge and funding deficits, to enhance scientific and environmental education, or as a form of participatory democracy (Science Communication Unit -UWE 2013). Yet, it has also been subject to critiques mainly disputing scientific validity of the results provided that the data is collected (and analyzed) by untrained individuals (Underwood and Chapman 2002).

However, I contend that the validity of any scientific claim depends on how the data collection and the analysis are performed (and not necessarily on who is involved). Extensive research examining the rigor of citizen science projects draws a relatively positive picture, thanks to the increasing sophistication of the instrumentation available for such projects (Crall *et al*. 2011; Gollan *et al*. 2012; Stokes *et al.* 1990) and to different strategies used to resolve data quality issues (Riesch and Potter 2014; Science Communication Unit -UWE 2013). Similar to the case of professional science, we believe that a clear explanation of the methodology, the limitations of the data, and the challenges encountered can also be helpful to ensure the reliability of findings.

Following increasing public concern about the impacts of air pollution and the development and dissemination of low-cost air pollution sensors and techniques, air pollution monitoring is currently the subject of a number citizen science projects, including the CAPTOR project (www.captor-project.eu), Hackair (www.hackair.eu), or Lucht Pijp (www.luchtpijp.be) (for more references, see ECSA 2019). While all of these projects share an ambition to advance air pollution research beyond the limits inherent to professional science and governmental monitoring efforts, a number of challenges remain, notably the reliability of the sensors used (Castell *et al.* 2017; Kumar *et al*. 2015; Lewis and Edwards 2016). Citizen science can be used to explore complexity and elucidate unexplored questions, contributing to countering hegemonic sense-making and overcoming epistemic injustice (Ottinger 2017).

Air pollution in Brussels

Our citizen science study focuses on the Brussels Capital Region, Belgium, where all participants are mainly based. Air pollution concentration is monitored by the city's environmental protection agency through a network of 13 stations - five of which measure $PM_{2.5}$ - collecting data on various "typical" situations, characterized by different levels of traffic intensity and population density, urban topography, land-use. In addition, ad hoc studies are conducted by the agency or by research institutes (Bruxelles Environnement 2015). The data are combined with emissions inventories and with information on meteorological and topographic conditions, and are used to model pollution across the regional territory. According to IRCELINE, the interregional agency that compiles data across the country, $PM_{2.5}$ concentrations have decreased in the last 15 years. In 2016 the Belgian population was nowhere exposed to $PM_{2.5}$ annual mean concentrations above EU limit value of 25 $\mu g/m^3$, but 84.6% remained exposed to concentrations beyond threshold 10 $\mu g/m^3$ recommended by the World Health Organization, an increase in comparison to 2014 (irceline.be n.d.; see also da Schio *et al.* 2017 for a detailed overview of the mains issues at stake concerning air pollution in Brussels).

In recent years, air pollution has been at the centre of a public debate concerning both the sheer level of pollution (the main culprit is NO_2), but also the existing systems to monitor it. Numerous citizen groups have mobilised against air pollution, culminating in 2019 with the first General Assembly on Air (*Etats Generaux de l'Air de Bruxelles*). Universities, the administration, and civil society have engaged in different citizen science projects. The regional government has also been questioned in the context of a court case filed by the NGO Client Earth, and of an infringement procedure opened by the European commission (Chemin *et al.* 2019; da Schio and Vandenbroucke 2020).

Methodology and Data

The AirCasting Brussels Project

This research took place in the context of the AirCasting Brussels project, a living lab conducted by partners from academia (Vrije Universiteit Brussel), civil society (BRAL-Citizens Action Brussels), and different citizen groups (for a complete overview of the project methods and results, see Chemin *et al.* 2019:24–31). As part of the project, a group initially formed from the local citizens' movement "Bruxselair" decided to conduct the scientific study reported here. Between November 2017 and June 2018, twelve workshops were organized at intervals of two to four weeks. During the workshops, participants discussed and agreed on the specific research questions, the methods, and the desired outcome of the process. In the periods of time between the workshops, the participants conducted a series of measurement sessions. The citizen science approach we took implied a continuous process of consensus-making regarding research objectives and methods, which had to take into consideration the interests and ambitions of all the participants, their available time and skills, and the technologies. Most importantly, it meant engaging in research deemed to be relevant and useful in the context of their mobilization. The process led us to a methodology combining $PM_{2.5}$ averages with narrated experiences of the participants' typical weeks, which as "stories supported with data—or […] data situated within stories" has already proved to be a compelling strategy to address environmental hazards (Ottinger 2017:42).

Case-Study Based Geographical Analysis

The research is based on case study analysis, an approach considered to be particularly suitable to understand concrete problems and to incorporate the broadest range of contextual influences on a certain phenomenon (Baxter 2010).

Selection of cases

The selection of the cases was based on two principles. The citizen science approach meant that the (self-selected) members of the groups, their personal exposure, and their routines would be at the core of the study. The case-study approach, in turn, needed a strategic selection, to draw portraits that were illustrative of meaningful situations. The combination of these –possibly conflicting– principles led to a hybrid approach for the selection of cases. Based on collective reflection and the preliminary pollution measurements, we considered the possible drivers of different personal exposure and routines, including professional status, usual mode of transport, home living environment, age, and gender, as well as participants' personal geography. Building on these considerations, we selected four cases among the participants (Fig. 1) and identified three additional ones with additional characteristics.

The sample clearly does not allow us to draw a fully-fledged typology covering the entire resident population of Brussels, nor to identify a form of regional average for different activities and locations, which would be a potentially infinite exercise. While a quantitative study aims for statistical generalization and requires a *representative* (usually large) sample, a qualitative case study approach aims for analytical generalization (or transferability) and makes use of a *significant* sample (Baxter 2010). In our case, the seven profiles contributed to amass in-depth knowledge about particular Brussels residents experiencing the city in different ways, and to reflect on how their routines shape their personal exposure.

Because of the nature of the research project, the sample for this research mainly speaks to the situation of people whose personal routines reflect a degree of awareness about pollution and of motivation in reducing their own exposure (for example, an urban middle-class socioeconomic background, a high level of education, and a preference for active mobility and a sustainable lifestyle). While reducing the direct transferability of the research to a broader context, this bias has a critical advantage: it allows controlling for awareness about the problem and the motivation to address it, thus focusing on other dimensions such as differing capabilities and their implications. The seven cases nonetheless represent a degree of diversity, and include people of different ages, including a retiree and a child, and different professional situations and personal space-time trajectories.

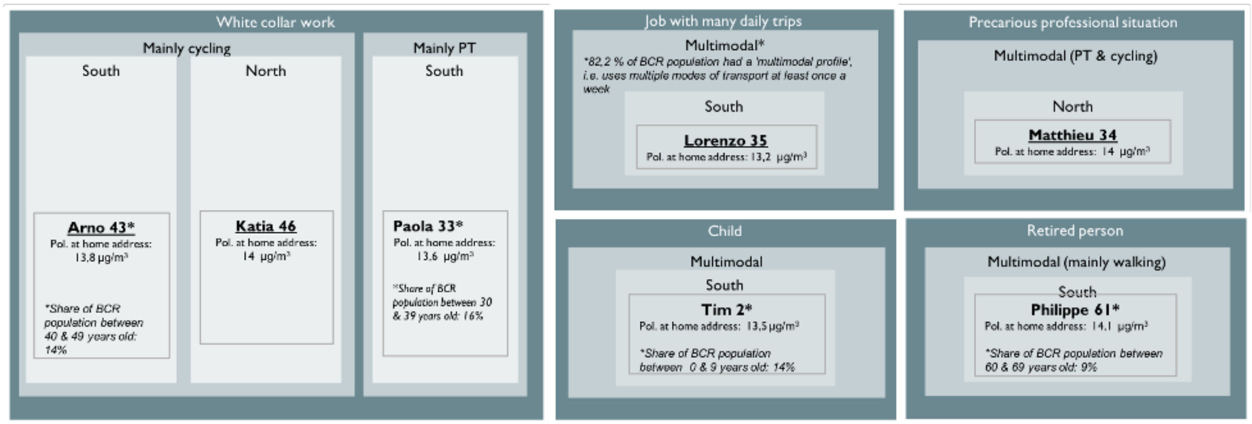


Fig. 1 - Summary of the sample including professional status, preferred mode of transport, geography, and age.

Notes: Participants could choose to use their first name or a pseudonym. BCR= Brussels Capital Region PT = public transport. (sources for population age: ibsa.brussels, 2019; for mobility: Lebrun et al. 2013; for air pollution irceline.be 2017)

Selection of meaningful activities

Each portrait comprises a set of defined “meaningful activities” representing a bundle of different parameters, such as time of day, duration, microenvironment, and location. For certain activities these parameters are always the same, while for others they vary. Katia’s activity “at work,” for instance, identifies the time spent at her desk (the same location, at the same time, under the same conditions), whereas Arno’s “leisure” refers to a combination of places and times (at the market on weekends, at the movies, in restaurants, etc.). We opted for this flexible approach in order to minimize the artificial design of typical activities imposed on people’s often atypical routines. This approach might make it difficult to rank these activities in absolute terms. At the same time, by closely reflecting participants’ real experiences, it allows us to consider them as practices interwoven in the whole organization of people’s space-time geographies.

Participants selected between four and six activities that were meaningful to them that occurred regularly (at least once a week) and together accounted for at least 75% of their typical week. We created a residual category comprising the weighted average exposure recorded for all the other activities.

Similar to the selection of participants, the selection of the activities was an exercise of balancing different priorities. To facilitate comparisons, it might have been helpful to have similar or equivalent activities across participants (and similar or equivalent to activities mentioned in existing literature). However, people have different geographies and the purpose of the research was precisely to explore the implications of these differences. For example, an activity such as “commuting” might be relevant for people who have a job and a regular route from home to work, but less so for those who are not in work or who have to deal with more complex and irregular logistics (because of multiple jobs, care-giving responsibilities, etc.). Broadly speaking, it should be noted, the time spent by the participants in the three bundles of activities described below, is in line with regional statistics on time use (Glorieux *et al.* 2015)

Monitoring exposure to air pollution

To collect data on personal exposure, we used the AirCasting infrastructure consisting of wearable monitors (AirBeams 1), the participants' smartphones (or smartphones made available through the project), and the AirCasting website and app (www.aircasting.org). The AirBeam is a wearable device using a light scattering method (with a Shinyei PPD60PV sensor) to measure $PM_{2.5}$, and reporting data in units of $\mu g/m^3$. Approximately once per second, the recordings are communicated via Bluetooth to the AirCasting Android app, which combines them with GPS data and time tags from the phone. At the end of each session, the data is uploaded to the AirCasting website server (Heimbinder and Besser 2014). AirBeam technology was field tested and compared with other low-cost air quality sensors as part of the US Environmental Protection Agency "CAIRSENSE" project, which found them to be among the best, with a correlation with the reference methods higher than most other devices (r = 0.65–0.66) (Jiao *et al.* 2016).

Between November 2017 and June 2018, participants used four AirBeams during different periods of time to record a series of sessions for each of the activities under scrutiny (a total of 432 sessions, resulting in 240 hours of recording and 864,000 data points for the study). While the AirBeam can provide $PM_{2.5}$ concentration values per second, we took the average of the whole session as a representative value. To combine sessions taken during different periods, without the influence of varying background concentrations, the measured data was computed with a daily correction factor, based on background air pollution measured by a reference monitoring station operated by the Brussels environmental protection agency (station 41R012 – IRM-KMI Uccle) that is considered to be representative of a residential environment and is used by the government as a reference station for background air pollution levels for the measured pollutants (Heene *et al*. 2016). It was chosen because with an average value of 11.61 $\mu g/m^3$ it presented the lowest $PM_{2.5}$ annual average concentration over the reference period (1 July 2017 to 30 June 2018). The observed temporal variation is representative for the study area.

To correct exposure data for background air pollution we applied a method developed by Dons and colleagues (2012:S4) (Table 1). A daily correction factor is particularly suitable for comparing activities when using wearable monitors. For example, it can show the difference between the average exposure during the same trip at peak time or off-peak. By comparison, greater temporal detail would be more suitable for comparing locations, for example, by emphasizing the difference between exposures in various parts of a journey regardless of the time they were made.

To estimate the typical exposure value for a given activity, we took the weighted average of all sessions recorded for that activity, corrected for background air pollution. The number of sessions for each activity was based on the participant availability. Only sessions longer than one minute were retained. A minimum of four valid sessions and 50 minutes of measurements were recorded for every activity (range 4–38 sessions; average per activity 13 sessions). Considering the higher variability of exposure, a minimum of eight sessions and 180 minutes were recorded for mobile activities (range 8–38 sessions; average per activity 20 sessions).

Table 1 - Schematic representation of the formulae used for the rescaling of personal measurements

Personal measurement > refsite_DailyAverage	*Personal measurement < refsite_DailyAverage*
Personal measurement_corr = Personal measurement + (refsite_YearlyAverage – refsite_DailyAverage)	**Personal measurement_corr** = Personal measurement * (refsite_YearlyAverage / refsite_DailyAverage)

Source: Dons et al., 2012.

Studying individual space-time trajectories

In addition to exposure data, we collected information on participants' space-time trajectories. We first compiled the basic elements of individual activities and bundles thereof from a written description provided by every participant. Information about time use (i.e. number of hours per week, per each activity) was combined with the exposure data to determine exposure burden values.

*Exposure burden = weighted & corrected avg. exposure * hours per week*

Between 15 and 30 October 2018, after the exposure portraits were produced and the differences/similarities emerged, I conducted an in-depth, semi-structured interview with each participant , mostly at their home or workplace.

In the first section of the interview, we built on the participant's description of their routine, detailing the material development of every activity, the meanings attributed to them, and exploring how particular space-time trajectories came to take place. In the second, we discussed how air pollution – understood as a general urban problem – came into the participant's everyday practices. We went through the same typical day, with a focus on when and how air pollution was perceivable and perceived, and on the concrete implications. We then conducted an overview of the participant's exposure portrait, and their reactions to it. Lastly, we discussed practical possibilities to reduce the participant's personal exposure and reflected on their ability to make different choices and willingness to do so. The verbatim transcriptions of the interviews were coded thematically and analyzed with the aid of NVIVO, a qualitative data management and analysis program. The data collected through the interviews was combined with the data from the AirBeams, providing the source for a sociological reading of individual exposure, including the representation of air pollution and its material and symbolic interaction with other dimensions of people's life.

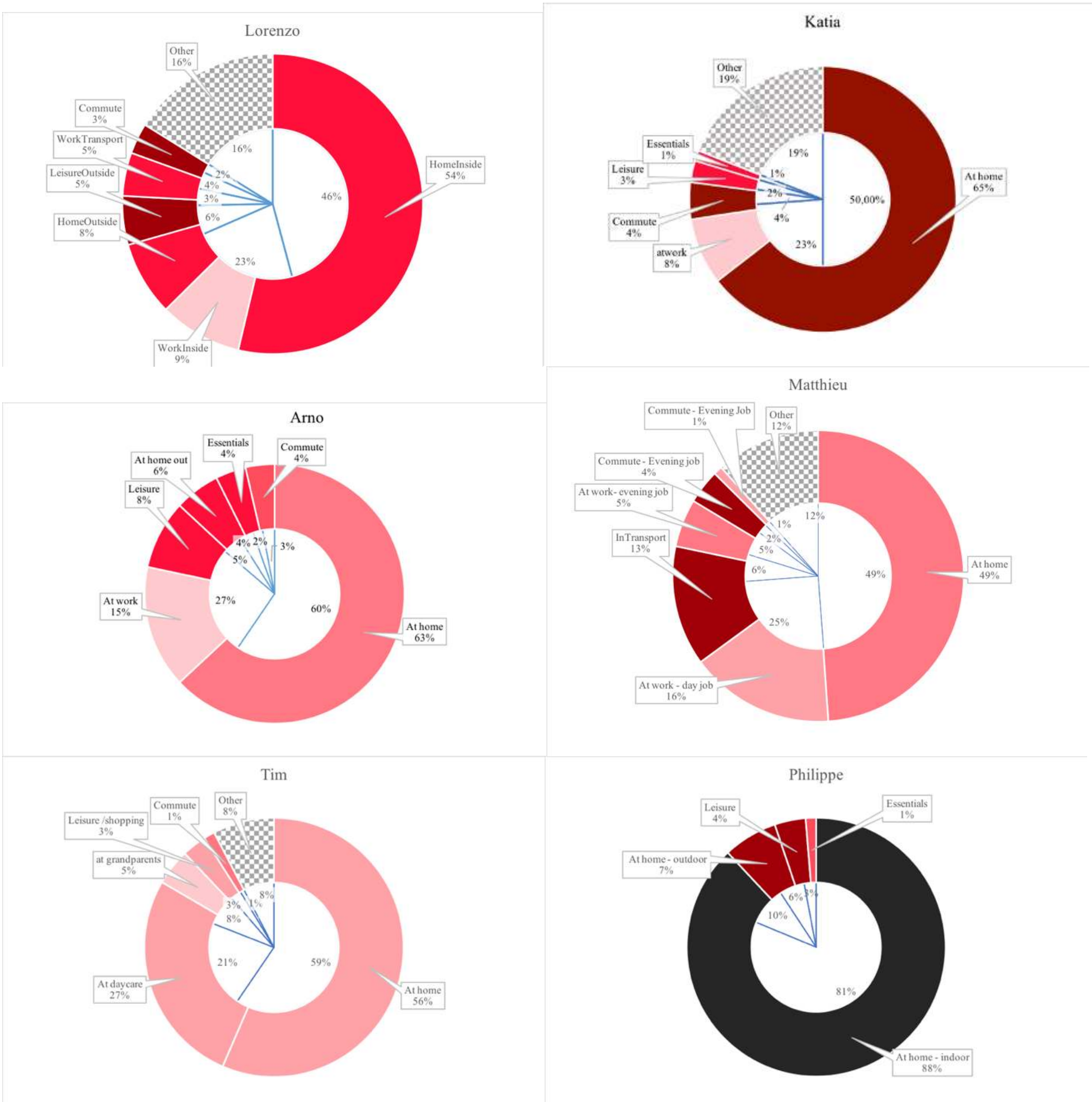
Arguably, interviews offer a number of merits and are consistent with social practice theory (Hitchings 2012). In particular, they have the potential to bring routine actions into the consciousness and trigger a process of self-evaluation. Interviews were preferred in the context of our citizen science approach where participants could voice their perspective as genuine subjects. Further, they not only allowed us to collect information about why and how things were done, but also to jointly reflect on how this could be changed.

Analysis and Discussion

I present the sociological and exposure data for the three activities that were most significant in terms of time, recurrence, and exposure: home time, the commute, and the main occupation (Table 2). These three broad categories possibly hide the complexity of individual routines, which is why I describe the individual cases together with the analysis of the differences among them and the common trends. We also chose to focus on the relative weight of each of the activities, both in terms of time use and the exposure burden, because we wanted to make comparisons within our study rather than with other studies using different methods and technologies (Fig.2).

Table 2. Summary table of individual exposure burdens

	Activity	Average exposure to $PM_{2.5}$ (µg/m^3)	Time use (hours per week)	Time use	Exposure burden		Activity	Average exposure to $PM_{2.5}$ (µg/m^3)	Time use (hours per week)	Time use	Exposure burden
Lorenzo	Work inside	8.43	38	23%	8.9%	Paola	At home	12.68	90	54%	38%
	Home inside	25.06	77	46%	53.7%		Commuting w. child	19.88	11	6%	7%
	Home outside	27.41	10.5	6%	8.0%		At work	30.99	30	17.9%	31%
	Work transport	27.95	6	3.6%	4.7%		Commute	35.36	2	1.2%	2%
	Leisure outside	31.52	6	3.6%	5.3%		Other	17.75	35	21%	21%
	Commute	35.69	3.3	2.0%	3.3%						
	Other	21.40	27.2	16%	16.2%						
Katia	At work	8.27	40	23.81%	8.10%	Philippe	Home inside	57	137	81%	88%
	Essentials	25.76	2	1.19%	1.26%		Home outside	37	16	10%	7%
	Leisure	26.82	4	2.38%	2.62%		Leisure	33	11	6%	4%
	Commute	30.53	6	3.57%	4.48%		Essentials	23	5	3%	1%
	At home	31.39	84	50%	64.49%						
	Other	24.33	32	19.05%	19%						
Arno	At work	9.04	45	26.79%	15.29%	Tim	At home	12	100	60%	56%
	At home	16.77	100	59.52%	63.05%		At daycare	15	36	21%	27%
	Commute	19.20	5	2.98%	3.61%		Grandparents	7	13	8%	5%
	Home outside	25.13	6	3.57%	5.67%		Leisure/shopping	14	5	3%	3%
	Essentials	25.15	4	2.38%	3.78%		Commute	17	2	1%	1%
	Leisure	28.60	8	4.76%	8.60%		Other	12	13	8%	8%
Matthieu	At work (day job)	11	42	25%	16.06%		$PM_{2.5}$ yearly concentration at home address as indicated by static pollution map (µg/m^3) - www.irceline.be				
	Commute (evening Job)	14	2	1.19%	0.97%		**Lorenzo**	13.2			
	At work (evening)	17	9	5.36%	5.33%		**Katia**	14.0			
	At home	17	82	48.81%	48.89%		**Arno**	13.8			
	Commute (day Job)	31	3.5	2.08%	3.80%		**Matthieu**	14.0			
	In transport	38	10	5.95%	13.34%		**Paola**	13.6			
	Other	17	19.5	12%	12%		**Philippe**	14.1			
							Tim	13.5			



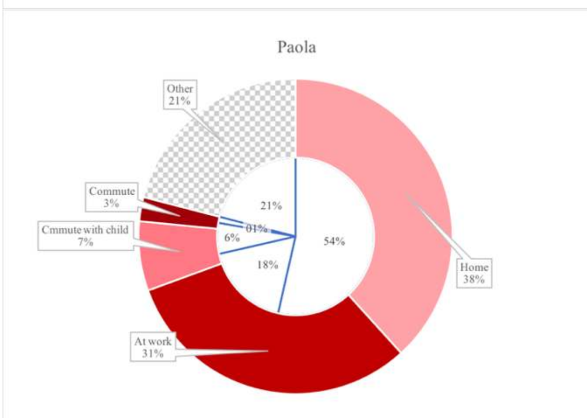


Figure 2 - Relative weight of participants' activities in terms of time dedicated to it (internal pie chart) and exposure burden (external annulus). The difference between internal and external values are indicative of how the time share taken by activities, can be substantially different from the exposure burden that characterize them.

Home Time

"Home time" is the initial and the final activity in all participants' weekly routine, comprising between 50% and 80% of their time. This is unsurprising since it includes sleeping time and largely corresponds to national and regional time-use (Glorieux *et al*. 2015). All the participants' homes were located in an urban environment within Brussels' regional borders, and some included an open space such as a garden or a terrace where measurements were also taken.

Thus "home time" is the most important component of all participants' exposure, albeit with differences. For example, Paola's relatively low exposure level at home means it only comprises 38% of her total exposure burden (vs. 54% of time spent at home), while for Katia, who lives in a first-floor apartment facing a busy street, her home time is 50% percent of her week but up to 64% of her exposure burden. On the other hand Philippe, having retired just a few weeks before the measurement campaign, spent more than 80% of his week at home, and because he smokes, the $PM_{2.5}$ concentration level at his home was the highest recorded in our sample at 88% of his exposure burden.

Participants did not perceive their homes to have worrying levels of pollution. They tended to associate pollution with the visible or audible presence of its sources, and thus to underestimate the presence of pollution in their absence, for example, a lack of traffic noise.

In the interviews, we also focused on questions of change, discussing cases where it had actually taken place, as well as hypothetical future changes. Overall, it appeared that changes with respect to "home" activity were relatively rare, or anyway difficult to speak of, as home time was in some way a "residual" activity to which people gave little thought (e.g., "I am at home when I am not anywhere else"). To some extent, participants spoke about small behavioral changes they had adopted to reduce exposure, also as a consequence of the AirCasting project. Lorenzo, for instance, said he had stopped letting people smoke on his terrace once the AirBeam showed how much the $PM_{2.5}$ concentration rose. Paola and two-year-old Tim's parents said they adapted the way they ventilated their apartment, either using rear-facing windows, or avoiding opening them at all during peak hours.

The most obvious change was actual or planned relocation. Participants had different reasons why they had moved, or would, including willingness to buy an apartment or as a consequence of relationship change (moving in with a partner or leaving to live alone). The main criterion for choosing a location was a neighborhood's geographic accessibility, both in terms of connectivity (for example, access to the highway or to public transport) or proximity (for example, to family, friends, or amenities). Different forms of path dependencies , such as having grown up or having studied in the area, or the willingness to live in a specific urban environment, were also relevant. Respondents living with family or friends emphasized that moving was always the outcome of a compromise. Some also admitted choosing on the basis of their own feelings and aesthetic appreciation of an apartment (Katia and Matthieu) or of a neighborhood without further rationalization (Arno). Participants did not mention affordability. This might be due to the fact that they were all relatively comfortable with what they had, and because it appeared obvious that they could only live somewhere they could afford. The presence of nuisances (and the willingness to avoid them) had surprisingly little weight, although all participants stated that pollution was something they had considered. Both Arno and Tim's mother mentioned proximity to traffic as one criterion among others for not choosing a particular building, and therefore possibly served as some form of proxy for pollution and other nuisances.

Air pollution did not emerge as the main determinant in relocation decisions. Those participants actively looking for a new home at the time of the interview said they had considered air pollution, but were aware that pollution was only one of many criteria and noted that relocation would likely only occur once, if at all. Conversely, others seemed to be somewhat fatalistic and said that moving was unlikely to significantly affect their exposure, unless it came with a drastic (and generally unrealistic) lifestyle change.

The Commute

The commute refers to participants' trips from home to the place of their main activity or activities and back, including all possible stops, shortcuts, and detours. This is partly because of the differences in the focus of their activities. Family-related responsibilities (for example, dropping-off and picking-up a child for Lorenzo and Paola), or shopping-related stopovers (e.g. Arno and Katia) were always or often part of everyday commuting, influencing the itinerary in different ways and sometimes significantly increasing transport time. The participants' professional status also had an impact. For example, Matthieu had multiple jobs, resulting in longer and more articulated commuting trips, or Philippe, retired, who did not consider commuting as a standalone activity. There were also differences in transport modes, with regular cycling being somewhat overrepresented in our sample: Katia, Lorenzo, and Arno commuted virtually every day by bicycle or electric bike, Paola was a frequent public transport user (bus and tram), and Matthieu reported choosing his mode of travel every morning. Lastly, Tim's commute included being carried on his father's shoulders, travelling on his parent's bicycle, or by car.

In contrast to home time, the exposure burden from commuting is typically characterized by a limited time variable (between 1% and 10% of a typical week), but by high absolute and relative levels of exposure. Reflecting the measured data to a great extent, participants reported their commute as the pollution hotspot in their routines. They all referenced the sight or noise of the ubiquitous traffic as main culprit. Further, they described traffic as a broader nuisance, of which pollution was just one dimension among many. As noted above, this led to underestimates of the presence of pollution on quieter routes further away from heavy traffic. Sensing less or more pollution went hand in hand with other feelings of danger and physical threat, or of comfort and safety. For example, Tim's mother mentioned that she was aware of the difficulty in determining whether the small streets she used were actually less polluted, but that "*psychologically*" it seemed a better choice - the smaller streets not only appeared to be less polluted, but were also calmer and more pleasant than the larger roads.

Participants also spoke about their physical sensations, such as the visibility of air pollution and its bad smell, which was noted both as a way to estimate air pollution levels and also itself a form of olfactory nuisance. Pollution was also felt through its impact on the respondents' health. Arno, for instance, spoke of the experiences of his partner, who suffered from asthma and had realized after a few crises made her aware of her high vulnerability during pollution peaks that she should leave her bicycle at home and go to work by public transport.

When discussing the drivers and the explanations for their routines, and how they went about change, participants mainly focused on two aspects of their commute: the mode of transport and the itinerary, and clearly identified the time and the reasons why they had adopted them. In particular, the itinerary was chosen with web based and paper maps to find the preferred trade-off between saving time and avoiding different nuisances. These included traffic –referred to as source of discomfort, danger, and sometimes as an explicit source of pollution – but also various features of the physical environment (for example, cobblestones, tram rails, and inclines). With regard to the mode of transport, people referred again to saving time, but also to other motivating factors (such as enjoying cycling) and constraints (for example, the physical ability to cycle, or the lack of car ownership). It should be emphasized, however, that the choices were always limited by the available alternatives.

Overall, the interviews revealed different motivations for choice of commute mode and itinerary. For some participants, the adoption of a certain combination of mode and itinerary seemed very much a rational decision in response to specific experiences (such as major renovation works on the commuting route, or a shutdown of public transport). Others felt that they only had one reasonable option available, either in terms of mode or itinerary. Matthieu, for example, stated that he decided on the mode of transport and itinerary for every trip, although considering his professional situation, he spent a relatively large amount of time travelling, a matter over which he had actually had no choice.

The participants' awareness of pollution influenced their commuting practices, at least to some extent. Paola, for instance, said she kept a certain distance from the pavement edge to stay clear of pollution and when pregnant was even more careful. Katia stated that she tried to control her breathing and occasionally used a scarf to cover her face (even though she recognized this might only help to reduce the bad smell). Tim's parents started to use only the recirculation setting for ventilating the car, after taking measurements with the AirBeam. When asked about opportunities to reduce their exposure further, participants remained somewhat skeptical about the actual possibilities for change. Lorenzo and Arno, for instance, said they would be very inclined, within certain limits, to change their commuting practices to reduce their exposure. Reducing exposure would still be only one of the criteria when choosing the itinerary to get to work, with saving time and avoiding traffic remaining the most important ones. Lastly, for Katia and Philippe it seemed simply impossible to further reduce their exposure. Although Katia she said that she was already using the "greenest" mode and itinerary, Philippe proved somewhat cynical and skeptical regarding avoiding pollution.

Main Occupation

"Main occupation" represents between 30 and 51 hours of time spent per week. Our sample reflects a variety of socio-professional situations with different space-time patterns that exist in Brussels. In particular, two participants regularly worked in an office: Arno as a technician in the local TV network, and Katia as a freelance copywriter based in a co-working space. Lorenzo worked as a controller for an auditing company, involving regular trips throughout the country, and Paola was a teacher at a primary school in Brussels lowlands. Matthieu's professional situation was representative of those that combine different activities in different places and cannot easily be labeled. At the time of the project he was a trainee accountant, but was also working evening shifts in theater in the city center. Tim went to a daycare center in his neighborhood three or four days a week. As with commuting, Philippe's case was again an exception. A recent retiree, he said that – at least for the present – he was unable to identify a regular "main occupation."

Office time was found to be the activity presenting the lowest levels of exposure, in line with other Belgium-focused research (Bruxelles Environnement 2017; Dons *et al*. 2011). Low pollution levels were reflected by participants' perceptions of their office as a space separated, almost sealed off, from their daily routines. Most participants indicated that pollution never "entered" their office, physically or metaphorically; a feeling of safety that even extended to the company car. However, the feeling faded as soon as they went out. This was particularly clear in the case of Arno (15% of exposure burden vs. 27% of time use), who explicitly said he never "saw" pollution in his office, and of Katia (8% of exposure burden vs. 24% of time use), who felt she could finally breathe once in her office. Both of Matthieu's workplaces had moderate levels of pollution (a total of 21% of exposure burden vs. 31% of time use). While Lorenzo's office showed among the lowest concentrations recorded in the project (10% of exposure burden vs. 23% of time use), this was partially offset by his frequent business trips across the country, representing 5% of his exposure burden vs. less than 4% of time use (6 hours per week on average).

Tim's mother said that she had overestimated air pollution at the daycare center, and she was surprised that the measuring showed only moderate levels. Her expectation was possibly due to the close proximity of the center, and particularly its courtyard, to a heavily trafficked road, which in fact had a lower than expected impact on $PM_{2.5}$ concentration. In relative terms, nevertheless, the average exposure at the daycare center was found to be somewhat higher than at home and during leisure, and was second only to transport (27% of exposure burden vs. 21% of time use). By contrast, Paola's work time was the main culprit in her exposure portrait, with almost a third of the exposure burden vs. just over a sixth of her time, due to the very high pollution levels in the area despite the appearance of a relatively healthy environment due to the presence of trees on the terrace and the school being a reasonable distance from the street.

When discussing their main occupation, on one level participants spoke of their day-to-day professional routines, which were generally were treated as a given, leaving very little room to maneuver, while on another, describing how they come to be in their current employment (or daycare), they revealed a much greater sense of agency and potential for choice. We decided not to explore their motivation as this possibly depended on innumerable factors and is anyway outside of the scope of this study. Instead, the interviews resulted in promoting the location of the participants' workplaces as an entry point to examine their practices. In most cases, people stated they had set what they considered acceptable geographical boundaries and looked for suitable jobs within them. The relative proximity to or connections with their home location came, in some cases, as an unexpected "bonus." The strictness of these boundaries was related to whether people were already living in Brussels when they had started their current job. Those, like Arno and Lorenzo, who moved to Brussels just before starting (or because of) their current job had set relatively loose boundaries, such as the Brussels-Capital Region or the metropolitan area. Others, such as Katia and Matthieu (but also Paola, anticipating her next job), seemingly placed higher importance on proximity or specific areas. Tim's case differs, proximity and location in relation to his parents' work was one of the main elements for selecting a daycare center, rather than an external boundary. In his case, the main limit was simply the availability of places in neighborhood daycare facilities.

Air pollution was not a prominent factor in previous work-related choices or in speculation about the future. Participants felt they had very little capacity to change their exposure at their main occupation. At the same time, as noted, their workplace was often the place where pollution was lowest and anyway least visible. In other words, even if participants felt powerless, they also perceived little urgency to change and admitted that they would only adopt drastic solutions if the pollution threshold increased substantially. Considerations about pollution did play a greater role when children were involved (here, Tim, or Paola in the context of pregnancy), but the actual possibilities to do things otherwise remained limited and many possibly conflicting priorities still needed to be balanced.

Table 3. Summary table of Where and When People are Exposed, and on Why it is Difficult to Avoid

	Home Time	**The Commute**	**Main Occupation**
Task's contribution to overall pollution exposure	The high share of time-use results in highest contribution to the exposure burden	High absolute and relative levels of exposure. The limited share in time-use results in a small contribution to exposure burden	Office time is found to be the activity presenting the lowest levels of exposure
Perceived exposure	Pollution is not perceived as worrying, unless in the presence of other traffic-related nuisances	Highest concerns for pollution are found here, reflecting the ubiquitous presence of motorized traffic.	Pollution is barely an issue of concern. Workspace is depicted as "sealed off" from the rest
People's capacity to modify practices	Home's choice is contingent to a wide range of path dependencies and priorities. Presence of pollution is only one among many criteria.	Possibility to change exists but reflects a restricted number of available alternatives. Awareness about pollution plays a role in commuting practices (albeit within limits).	Pollution is not a prominent factor in work-related choices. Room for maneuver seems extremely limited

Conclusion

In the context of increasing concern about air pollution and its impact on human health, I have described a citizen science project adopting an original strategy to study the interaction between people and their environment. In particular, the project focused on personal exposure to $PM_{2.5}$ throughout a typical week: that is, on its absolute level at different times and in different locations, on participants' perceptions of it, and on how both are influenced by and themselves influence the organization of daily routines. In developing our approach, we built on different areas of air pollution research. These range from the natural to the social sciences, and include studies on activity-based exposure monitoring, on social practices and space-time trajectories, and on citizen science. Combining these different perspectives allowed us to develop a comprehensive account of how air pollution "enters" - materially and symbolically - into people's routine and how people can avoid it.

The people-based approach in particular, allowed us to go beyond the static picture of average concentration at home address and to depict multiple situations in which air pollution becomes visible or invisible, an obstacle to circumvent or an unavoidable burden, a real hazard or a label for something else. If the five stations of the regional telemetric network provide $PM_{2.5}$ trends in different typical urban environments, our seven cases provide as many typical space-time trajectories of Brussels residents. Although obviously limited to a subset of the possible exposure profiles, the sample provided insights on the differences that exist - inter alia - in relation to age, personal geography, professional situation, or care-giving responsibilities.

Further, the portraits highlight the nuances of people's personal exposure, revealing different exposure levels within the same person's space-time trajectory, with the main culprits for individual exposure being home (because of the time variable) and commute (because of the exposure variable). Main occupation represents a relatively low exposure burden, with some exceptions. In addition, our study allows comparison between individuals' situations. Home time, for instance, can represent a very different burden depending on residence configuration, but also age and daily habits. Similarly, transport time is not just a matter of itinerary, but includes schedules, motivations, stopovers, and actual ability to take certain transport modes. These results exceed by far the illustrative capacity of maps and indexes and put emphasis on the interest to re-focus air pollution research around people's space-time geographies rather than merely taking a place-based entry point.

The measurements are partially reflected in perceptions and representations of people who sense air pollution throughout their space-time trajectories, especially, but not exclusively, while using transport. While sight and smell play a role, our participants, sometimes unwittingly, inferred pollutant concentration from the presence of motorized traffic, one of its main sources. At the same time, they tended to presume cleaner air indoors, in less trafficked, quieter areas, or in the presence of urban greenery. Air pollution is not a nuisance; It serves as a cautionary note of for a broader set of motorized traffic related problems. In this context, artifacts placed in public spaces or mobile phone apps sourcing location-specific data have promising potential in enhancing people's physical perceptions.

While exposure to air pollution is a collective problem, it enters the individual sphere as a health burden and occasionally as a physical barrier to certain practices. Our analysis shows that, broadly, the reasons why people come to be exposed are only incidentally related to air pollution. Other factors, related for instance to established social relations, the housing and labor market, time constraints, various kinds of path dependencies, and the sheer availability of alternatives are ostensibly more important in determining their space-time trajectories

Overall, individuals' degree of agency to avoid air pollution is hindered by the relative stickiness of space-time trajectories. Awareness of air pollution, physical perceptions, and even personal monitoring of exposure do not seem to change this. Even among people with an above-average concern for the problem, air pollution is only one of the numerous elements (and by no means the dominant one) influencing their practices and their dynamic combination. In particular, the study shows how air pollution is or can be one of the elements influencing the outcome of given transformative events (for example, relocating, starting a new job, or using a map to find the best commuting route), but it becomes almost irrelevant once a certain practice has been established.

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References

Baxter, Jamie
2010 Case Studies in Qualitative Research. *In* Qualitative Research Methods in Human Geography. 3rd edition. Oxford University Press.

Blue, Stanley, Elizabeth Shove, Chris Carmona, and Michael P. Kelly
2016 Theories of Practice and Public Health: Understanding (Un)Healthy Practices. Critical Public Health 26(1): 36–50.

Bruxelles Environnement
2015 05. Les Accords Internationaux et Leurs Implications En Matière de Fourniture de Données : Les Polluants Suivis En Région de Bruxelles-Capitale. http://document.environnement.brussels/opac_css/index.php?lvl=notice_display&id=8888.

2017 Cartogrpahie Du Black Carbon En Région Bruxelloise. Bruxelles Environnement IBGE – Division Labo, santé et indicateurs. http://www.environnement.brussels/news/la-pollution-au-black-carbon-touche-differemment-les-bruxellois-selon-le-mode-de-transport-et.

Castell, Nuria, Franck R. Dauge, Philipp Schneider, et al.
2017 Can Commercial Low-Cost Sensor Platforms Contribute to Air Quality Monitoring and Exposure Estimates? Environment International 99: 293–302.

Chemin, Lievin, Nicola da Schio, and Tim Cassiers
2019 Citzen Sceince: Collective Knowledge Empowers. Brussels, Belgium: BRAL & Cosmopolis. https://bral.brussels/nl/artikel/citizen-science-collective-knowledge-empowers.

Crall, Alycia W., Gregory J. Newman, Thomas J. Stohlgren, et al.
2011 Assessing Citizen Science Data Quality: An Invasive Species Case Study. Conservation Letters 4(6): 433–442.

Dewulf, Bart, Tijs Neutens, Wouter Lefebvre, et al.
2016 Dynamic Assessment of Exposure to Air Pollution Using Mobile Phone Data. International Journal of Health Geographics 15: 14.

Dons, Evi, Luc Int Panis, Martine Van Poppel, et al.
2011 Impact of Time–Activity Patterns on Personal Exposure to Black Carbon. Atmospheric Environment 45(21): 3594–3602.

Dons, Evi, Luc Int Panis, Martine Van Poppel, Jan Theunis, and Geert Wets
2012 Personal Exposure to Black Carbon in Transport Microenvironments. Atmospheric Environment 55: 392–398.

ECSA, ed.
2019 Policy Brief_European Clean Air Day_20June2019.Pdf. https://cleanairday.eu/.

EEA
2017 Air Quality in Europe: 2017 Report. Publication. https://www.eea.europa.eu/publications/air-quality-in-europe-2017, accessed October 13, 2017.

2018 Air Quality in Europe - 2018. Publication. European Environment Agency. https://www.eea.europa.eu/publications/air-quality-in-europe-2018, accessed August 28, 2019.

European Parliament
2019 A Europe That Protects: Clean Air for All. http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2019-0186+0+DOC+XML+V0//EN&language=EN, accessed March 20, 2019.

Glorieux, I, J. Minnen, T.P. van Tienoven, and et al.
2015 Website "Belgisch Tijdsbudgetonderzoek", Onderzoeksgroep TOR Vrije Universiteit Brussel & AD Statistiek – Statistics Belgium, Brussel. www.time-use.be, accessed September 6, 2018.

Gollan, John, Lisa Lobry de Bruyn, Nick Reid, and Lance Wilkie
2012 Can Volunteers Collect Data That Are Comparable to Professional Scientists? A Study of Variables Used in Monitoring the Outcomes of Ecosystem Rehabilitation. Environmental Management 50(5): 969–978.

Haklay, Muki
2013 Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. *In* Crowdsourcing Geographic Knowledge. Daniel Sui, Sarah Elwood, and Michael Goodchild, eds. Pp. 105–122. Dordrecht: Springer Netherlands. http://www.springerlink.com/index/10.1007/978-94-007-4587-2_7, accessed July 8, 2016.

Heene, B., F. Beaujean, P. Declerck, et al.
2016 Evaluation de La Qualité de l'air Dans Le Pentagone de La Région de Bruxelles-Capitale. Brussels Environment. http://bral.brussels/sites/default/files/bijlagen/BIM_Brasseur_Evaluation_QA_Pentagone_Rapport_BRAL_ExpAIR_03032016.pdf, accessed February 2, 2017.

Heimbinder, Michael, and Alex Besser
2014 AirBeam Technical Specifications, Operation & Performance : Taking Space. http://www.takingspace.org/airbeam-technical-specifications-operation-performance/, accessed July 5, 2018.

Hitchings, Russell
2011 Researching Air-Conditioning Addiction and Ways of Puncturing Practice: Professional Office Workers and the Decision to Go Outside. Environment and Planning A 43(12): 2838–2856.

2012 People Can Talk about Their Practices. Area 44(1): 61–67.

Hitchings, Russell, and Alan Latham
2017 How ‘Social’ Is Recreational Running? Findings from a Qualitative Study in London and Implications for Public Health Promotion. Health & Place 46: 337–343.

Hodgson, Antonia, and Russell Hitchings
2018 Urban Air Pollution Perception through the Experience of Social Practices: Talking about Breathing with Recreational Runners in London. Health & Place 53: 26–33.

Int Panis, Luc
2010 New Directions: Air Pollution Epidemiology Can Benefit from Activity-Based Models. Atmospheric Environment 44(7): 1003–1004.

Int Panis, Luc, Bas de Geus, Grégory Vandenbulcke, et al.
2010 Exposure to Particulate Matter in Traffic: A Comparison of Cyclists and Car Passengers. Atmospheric Environment 44(19): 2263–2270.

irceline.be
N.d. Belgian Interregional Environment Agency (IRCEL - CELINE) — English. Http://Irceline.Be/. http://www.irceline.be/en, accessed February 7, 2017.

Jiao, Wan, Gayle Hagler, Ronald Williams, et al.
2016 Community Air Sensor Network (CAIRSENSE) Project: Evaluation of Low-Cost Sensor Performance in a Suburban Environment in the Southeastern United States. Atmospheric Measurement Techniques 9(11): 5281–5292.

Kumar, Prashant, Lidia Morawska, Claudio Martani, et al.
2015 The Rise of Low-Cost Sensing for Managing Air Pollution in Cities. Environment International 75: 199–205.

Latham, Alan, and Peter R H Wood
2015 Inhabiting Infrastructure: Exploring the Interactional Spaces of Urban Cycling. Environment and Planning A 47(2): 300–319.

Lewis, Alastair, and Peter Edwards
2016 Validate Personal Air-Pollution Sensors. Nature News 535(7610): 29.

Lim, Stephen S., Theo Vos, Abraham D. Flaxman, et al.
2012 A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990–2010: A Systematic Analysis for the Global Burden of Disease Study 2010. The Lancet 380(9859): 2224–2260.

Maller, Cecily Jane
2015 Understanding Health through Social Practices: Performance and Materiality in Everyday Life. Sociology of Health & Illness 37(1): 52–66.

Middleton, Jennie
2011 “I’m on Autopilot, I Just Follow the Route”: Exploring the Habits, Routines, and Decision-Making Practices of Everyday Urban Mobilities. Environment and Planning A: Economy and Space 43(12): 2857–2877.

de Nazelle, Audrey, Olivier Bode, and Juan Pablo Orjuela
2017 Comparison of Air Pollution Exposures in Active vs. Passive Travel Modes in European Cities: A Quantitative Review. Environment International 99: 151–160.

Ottinger, Gwen
2017 Making Sense of Citizen Science: Stories as a Hermeneutic Resource. Energy Research & Social Science 31. Narratives and Storytelling in Energy and Climate Change Research: 41–49.

Riesch, Hauke, and Clive Potter
2014 Citizen Science as Seen by Scientists: Methodological, Epistemological and Ethical Dimensions. Public Understanding of Science 23(1): 107–120.

da Schio, Nicola, Bas de Geus, and Catherine Bouland
2017 A Brief Guide to the Air of Brussels. Brussels Centre Observatory Portfolio #2. http://bco.bsi-brussels.be/a-brief-guide-to-the-air-of-brussels/, accessed November 21, 2017.

da Schio, Nicola, and Anneloes Vandenbroucke
2020 Les États Généraux de l’Air de Bruxelles 2019. *In* De Vijfhoek Voorbij. Het Metropolitane Stadscentrum van Brussel. Brussel. ULB en VUB PRESS.

Science Communication Unit -UWE
2013 Science for Environment Policy In- Depth Report: Environmental Citizen Science. University of the West of England, Bristol (UWE) for European Commission DG Environment. http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR9_en.pdf, accessed July 7, 2016.

Sexton, Ken, and P. Barry Ryan
1988 Assessment of Human Exposure to Air Pollution: Methods, Measurements, and Models. *In* Air Pollution, the Automobile, and Public Health Pp. 207–238. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK218147/, accessed March 6, 2019.

Shove, Elizabeth, Mika Pantzar, and Matt Watson
2012 The Dynamics of Social Practice: Everyday Life and How It Changes. Los Angeles: SAGE.

Shove, Elizabeth, and Nicola Spurling
2013 Sustainable Practices: Social Theory and Climate Change. London: Routledge.

Sorensen, Amanda E., and Rebecca C. Jordan
2016 Impacts and Implications of Researcher Identity and Academic Practice: Future Directions for Public Engagement and Ecological Research. Human Ecology 44(3): 375–391.

Steinle, Susanne, Stefan Reis, and Clive Eric Sabel
2013 Quantifying Human Exposure to Air Pollution—Moving from Static Monitoring to Spatio-Temporally Resolved Personal Exposure Assessment. Science of The Total Environment 443: 184–193.

Stokes, Pamela, Magda Havas, and Tom Brydges
1990 Public Participation and Volunteer Help in Monitoring Programs: An Assessment. Environmental Monitoring and Assessment 15(3): 225–229.

Strengers, Yolande, and Cecily Jane Maller, eds.
2014 Social Practices, Intervention and Sustainability: Beyond Behaviour Change. 1st edition. Routledge. https://www.taylorfrancis.com/books/9781315816494, accessed May 28, 2019.

Tong, Zheming, Yujiao Chen, Ali Malkawi, Gary Adamkiewicz, and John D. Spengler
2016 Quantifying the Impact of Traffic-Related Air Pollution on the Indoor Air Quality of a Naturally Ventilated Building. Environment International 89–90: 138–146.

Underwood, A. J., and M. G. Chapman
2002 Conservation of Coastal Organisms Depends on Scientific Realism, Not Community "Monitoring." *In* A Clash of Paradigms. http://publications.rzsnsw.org.au/doi/abs/10.7882/FS.2002.019, accessed August 25, 2016.

Walker, Gordon
2013 Inequality, Sustainability and Capability: Locating Justice in Social Practice. *In* Sustainable Practices Pp. 197–212. Routledge.

2014 Beyond Individual Responsibility: Sustainable Practices, Capabilities and the Case for a Rights-Based Politics of Social Change. *In* Social Practices, Intervention and Sustainability: Beyond Behaviour Change. London: Routledge.

WHO
2014 Burden of Disease from Ambient Air Pollution for 2012 — Summary of Results. WHO. http://www.who.int/phe/health_topics/outdoorair/databases/AAP_BoD_results_March2014.pdf, accessed September 8, 2017.

Zhu, Yifang, William C. Hinds, Margaret Krudysz, et al.

2005 Penetration of Freeway Ultrafine Particles into Indoor Environments. Journal of Aerosol Science 36(3): 303–322.