Understanding the underlying motivations and intentions behind actions to promote pro-social and pro-environmental behaviours : an application to transport mode choice

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Understanding the underlying motivations and intentions behind actions to promote pro-social and pro-environmental behaviours - An application to transport mode choice

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Abstract

The purpose of this thesis is to contribute through economic and psychological theories to a better understanding of the individual determinants to engage in pro-social and pro-environmental behaviours. Focusing on individual mobility practices, since they generate environmental and health externalities, this thesis identifies public policy levers to promote active mobility (public transport, bicycle and walking). The first chapter investigates the acceptability of low emission zones (LEZ) restricting the circulation of the most polluting cars, the second and third chapters explore the motivation and determinants of intentions to modal shift and the fourth chapter tests public interventions applicable not only in transportation but suitable to any other pro-social/pro-environmental behaviour. The Grenoble Metropolis is the field of study throughout the thesis, based on data collected through two population-based surveys and an online laboratory experiment. The first chapter studies the determinants of the acceptability of the residents of Grenoble for the project to implement a LEZ. The results of the bivariate analysis and logit regression demonstrate a general acceptability that is mainly determined by the individual positive attitudes and perceptions of the LEZ and less influenced by the socio-demographic characteristics. The second chapter analyses the motivation-intention to modal shift relation and the role of active mobility habits in this relation. Based on the Self-Determination Theory framework, the results of the mediation analysis using structural equation modelling show that developing self-determined motivation can encourage habits and intentions to shift to alternatives to the car. In contrast, strengthening non-self-determined motivations can be counterproductive. The third chapter tests the influence of presenting morbidity health risk information related to mobility practices on the intentions to modal shift. In a discrete choice experiment, two types of information are presented: 1) the public cardiovascular risk related to air pollution and 2) the individual cardiovascular risk related to physical activity thanks to active mobility. The discrete choice model estimates show a significant effect on mobility preferences of both types of information encouraging the choice of alternatives to the car. However, in communicating this information, just mentioning the possibility of health risk reduction seems to have more influence on the mobility preferences than emphasising the exact rate of this reduction. Taking a broader perspective than

the modal shift behaviour, the fourth chapter defines two primary explanations for the general refrain from pro-social/pro-environmental behaviours: 1) low real intentions or 2) high real intentions with difficulties in translating them into actual behaviour. Thus, to encourage desirable behaviours, this chapter tests in the context of a charity game two interventions: 1) a learning intervention on intentions to donate and 2) a default nudge intervention on the donation behaviour. The results demonstrate a short-term effect of both interventions with higher donations thanks to the nudge. However, the positive effect of giving on emotions is greater under the learning intervention.

Keywords: Transport choice, modal shift intention, public policy, DCE, mediation, laboratory experiment

Résumé

L'objectif de cette thèse est de contribuer, par le biais des théories économiques et psychologiques, à une meilleure compréhension des déterminants individuels pour l'engagement dans des comportements pro-sociaux et pro-environnementaux. En se focalisant sur les pratiques de mobilité individuelle du fait des externalités environnementales et sanitaires qu'elles génèrent, cette thèse identifie des leviers de politiques publiques permettant de promouvoir la mobilité active (transports publics, vélo et marche). Le premier chapitre évalue l'acceptabilité d'un exemple de ces politiques (Les Zones à Faibles Emissions, ZFE). Les deuxième et troisième chapitres explorent la motivation et les déterminants des intentions de report modal. Le quatrième chapitre teste des interventions publiques applicables non seulement au domaine des transports mais adaptées à tout autre comportement pro-social ou pro-environnemental. La Métropole de Grenoble constitue le terrain d'étude de l'ensemble de la thèse avec la réalisation de deux enquêtes et une expérience de laboratoire en ligne. Le premier chapitre étudie les déterminants de l'acceptabilité du projet de mise en place de ZFE restreignant la circulation des voitures les plus polluantes pour les habitants de Grenoble. Les résultats de l'analyse bivariée et de la régression logit démontrent une acceptabilité qui est principalement déterminée par les attitudes et perceptions individuelles positives de la ZFE et moins influencée par les caractéristiques socio-démographiques. Le deuxième chapitre analyse la relation motivation-intention de report modal et le rôle des habitudes de mobilité active dans cette relation. Se basant sur la théorie de l'autodétermination, les résultats de l'analyse de médiation par le biais des équations structurelles montrent que le développement de la motivation autodéterminée peut encourager les habitudes et les intentions de report vers des alternatives à la voiture. En revanche, le renforcement des motivations non autodéterminées peut être contre-productif. Le troisième chapitre teste l'influence de la présentation d'informations concernant les risques sanitaires de morbidités liés aux pratiques de mobilité sur les intentions de report modal. Dans une expérience de choix discret, deux types d'information sont présentés: 1) le risque cardiovasculaire public lié à la pollution atmosphérique et 2) le risque cardiovasculaire individuel lié à l'activité physique résultant de la mobilité active. Les estimations des modèles de choix discret montrent un effet significatif

sur les préférences de mobilité des deux types d'information encourageant le choix d'alternatives à la voiture. Cependant, lors de la communication de ces informations, la simple mention de la possibilité de réduire les risques sanitaires semble avoir plus d'influence sur les préférences de mobilité que celle du taux exact de cette réduction. En adoptant une perspective plus large que le comportement de report modal, le quatrième chapitre définit deux explications principales pour le renoncement à des comportements pro-sociaux ou pro-environnementaux: 1) des intentions réelles faibles ou 2) des intentions réelles élevées avec des difficultés à les traduire en comportement réel. Ainsi, pour encourager les comportements souhaitables, ce chapitre teste dans le contexte d'un jeu de charité deux interventions : 1) une intervention d'apprentissage appliquée sur les intentions de donner de l'argent et 2) une intervention de *nudge* par défaut appliquée sur le comportement de don. Les résultats démontrent un effet à court terme des deux interventions avec des dons plus élevés grâce au *nudge*. Cependant, l'effet positif du don sur les émotions est plus important dans le cadre de l'intervention d'apprentissage.

Mots-clés: Choix de transport, intention de report modal, politique publique, DCE, médiation, expérience de laboratoire.

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General Introduction

0.1 Context

0.1.1 Impacts of mobility practices

"Human civilisation is currently profoundly unsustainable" states the European Environment Agency (EEA) in its report entitled "growth without growth" (Strand et al., 2021). Economic and human development has been based on technological innovations in many fields such as industry or agriculture. This has been combined with significant developments in terms of land use which have led to decisive urban/rural space configurations influencing the transport systems. In addition to these developments, accessibility to low-cost fossil fuels has been a determining factor in bringing further changes in transportation systems and practices. This context led to the unbridled exploitation of the existing resources and to many impacts on the environment through different forms of pollution (air, water, soil, etc.) and climate change.

Individuals, industries and the government must jointly take responsibility for addressing the environmental crisis. The fight against pollution and climate change can be won only if it is carried out on all fronts whether from demand-side or from supply-side. The report of Dugast et al. (2019) distinguishes the contribution of each side to CO_2 reductions. With 11 tons of CO_2 emissions for an average French citizen in 2019, actions must be undertaken to reduce these emissions by 80% before 2050 and not exceed a global warming of +2°C compared to the pre-industrial era (Paris Agreement, 2015). Dugast et al. (2019) estimate that 60% reduction is attributed to collective efforts of the industries and the government (eg.policies to decarbonise the agricultural sector or technological innovations and in all the economic sectors). Besides, a 20% reduction is possible thanks to change in the everyday individual practices in regards to nutrition, mobility and housing choices to adopting pro-environmental behaviours (eg. cycling instead of using the car or recycling). Hence, behavioural changes are among the main solutions to encounter the environmental critical situation. The present thesis mainly focuses on this latter aspect allowing for a better understanding of the individual behavioural change to adopting pro-social

and pro-environmental behaviours, in particular for mobility practices.

This interest is motivated by the fact that since the mid-20th century, humanity has been living in a continued rapid growth known as the "Great Acceleration" (Steffen et al., 2015). It is characterised by a continued urbanisation: In 2021, 75% of the European population lives in urban areas (Statista, 2022) and this share is expected to reach 84% in 2050.[1] Rising real estate prices and rents in urban centers (Charlton, 2021) combined with increasingly efficient transportation based on low-cost fuels (Ostermeijer et al., 2022; Christiansen and Loftsgarden, 2011) have led to significant urban sprawl. Consequently, it encouraged people to move to the suburbs where housing is more affordable (Clark et al., 2018).

This situation influenced mobility practices since individuals rely more on the private car to commute and to access the farther amenities (Ostermeijer et al., 2022). Indeed, Kompil et al. (2019) found that a European person living in a city would have a local facility within 2.5km compared to 9km for someone living further from the city center. They also identified a higher walk-ability and cycling potential for those closer to city center since 81% of the people in Europe have a local service within 5km distance which drops to 49% for subregional services.

Current particular modal share for road traffic in Europe shows a high dependency on the private vehicle[2]. This dependence on the private vehicle is very high in France. The evaluation of Cordier (2021) for the modal shares in the major cities in France shows the car as the main mode of transport (regardless of the purpose of the trip) with shares ranging between 49% for the residents in the city centers (compared to 12% for the public transport, 3% for the bicycle and 36% for walking) to 75% for those living in suburban areas (compared to 5.6% for the public transport, 1.2% for the bicycle and 18.5% for walking).

Even thought demand on alternatively-powered cars[3] in France grew significantly (32% increase between 2018 and 2019), the vast majority of the new cars are still powered by diesel motors (ACEA, 2019). In 2019, diesel vehicles consisted 60% of the French vehicle fleet (Babet et al., 2021) with a 7% increase in the number of registered new diesel vehicles between 2018 and 2019 (ACEA, 2019).

Considering the extended use of the private vehicle, road traffic is associated with many negative externalities: traffic congestion and accidents, air pollution, noise and vibrations, soil and water pollution, greenhouse gas emissions, changing eco-urban landscape (Pîrlea and Burlacu, 2014). Focusing on air pollution, different

[1] https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation_en

[2] https://www.eea.europa.eu/data-and-maps/indicators/passenger-transport-demand-outlook-from-eea/passenger-transport-demand-outlook-from-1

[3] Electrically-chargeable vehicles, hybrid electric vehicles and vehicles running on ethanol, liquid petroleum gas or natural gas.

metrics have been used to quantify and monitor the environmental impact of road traffic among which are the following three: emissions, concentration and exposure.

First, emissions measurement is defined as "the process of measuring the amount of pollutants, in a gaseous or particulate form, being emitted to the air from a specific source" (EPA, 2021b) such as the emission of fine particles ($PM_{2.5}$ and PM_{10}) and pollutants like NO_x. Such pollutants are more particularly emitted because of the combustion. Fine particles are also emitted due to the friction of the tyres on the tarmac, the suspension of particles in the air when vehicles pass by and by the car brakes. France is among the top three European countries in terms of emissions of these air pollutants. It is the highest emitter of fine particles (EEA, 2019) with 121,300 tons of total emitted $PM_{2.5}$ and 773,800 tons of total emitted NO_x in 2019 (See the interactive dashboard of the European Environment Agency).

The main contributing sector to the high levels of emitted $PM_{2.5}$ (50% of the total emissions) is the residential and commercial activities (mainly wood heating). Road transport, with a share of 17%, is the second most emitting sector. $PM_{2.5}$ emissions come in particular from private vehicles. However, road transport is far ahead as the first contributor to the NO_x emissions with a 56% share in 2019 in France among which 49% is caused by the private vehicles. The second and third contributors of NO_x emissions are agriculture and manufacturing contributing by, respectively, 17% and 13% to the total emissions.

Second, measuring the concentration of an air pollutant is calculating "the amount of material per unit volume of air" (Kennedy et al., 1988). In the case of road traffic, concentration of air pollutants is higher closer to the main roads (SDES, 2022). To guarantee a better air quality, the World Health Organization (WHO) has established guidelines on levels of air pollutants (WHO, 2021). For instance, the most recent guidelines indicate that the annual average concentrations of $PM_{2.5}$ should not exceed 5 $\mu g/m^3$ or that the annual average concentrations of NO_2 should not exceed 10 $\mu g/m^3$. These thresholds are widely used by policymakers as a reference for setting objectives to implement air quality improvement measures. In France, the pollutants concentration levels have been decreasing. For instance, there is a decrease of 50% of $PM_{2.5}$ concentration between 2009 and 2019: from 16 $\mu g/m^3$ to 8 $\mu g/m^3$ in metropolitan France (Citepa, 2020b). However, major French cities like Paris or Grenoble still exceed 5 $\mu g/m^3$ with levels reaching in 2021, respectively, 13.4 and 9.9 $\mu g/m^3$. Figure 1 presents other examples of European cities exceeding the 5 $\mu g/m^3$ recommended level.

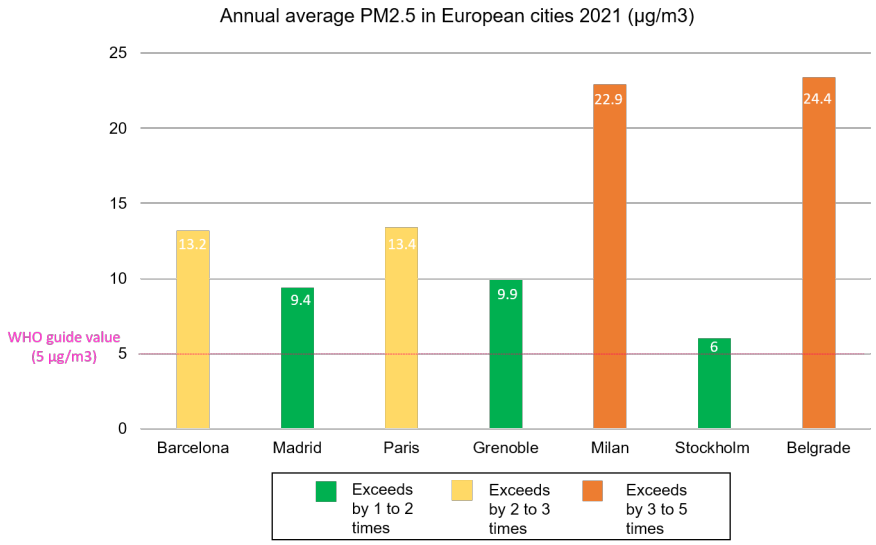

Figure 1: Average annual pollution of PM2.5 particles in 2021*

*Notes: Data from 2021 World Air Quality Report and its interactive world map: https://www.iqair.com/world-air-quality-report
The 2021 values are not different from those of 2019 (pre-COVID data) for these cities.

Third, pollution exposure is defined as an interaction between the pollutant and the human body "expressed quantitatively by a description of the duration of the contact and the relevant pollutant concentration" (Kennedy et al., 1988). WHO (2021) guidelines indicate that a 24-hour average population exposure should not exceed 15 $\mu g/m^3$ for $PM_{2.5}$ and 25 $\mu g/m^3$ for NO_2 more than three to four days per year. With the previously mentioned increased urbanisation and denser road traffic, larger shares of the population in urban areas are more at risk of being exposed to the poor air quality. Actually, in 2020, the European urban population was exposed to concentrations of pollutants above the WHO guidelines. 96% of the population is exposed to highly concentrated air with $PM_{2.5}$ and 89% share is exposed to high concentrations of NO_2 (EEA, 2022a).

These air pollutants cause numerous environmental and health impacts. On the one hand, NO_2 participates in the phenomenon of acid rain, which impoverishes the ecosystem and contributes to the formation of greenhouse gas. $PM_{2.5}$ also deteriorates air quality reducing visibility and damaging the soil, water and vegetation (US EPA, 2021). On the other hand, fine particles are a major concern for human health. The particles deeply penetrate in the lungs and blood streams increasing the risk of respiratory and heart diseases (eg. asthma, heart attacks) (EPA, 2021a; Citepa, 2020b). They are also considered carcinogenic and cause premature deaths (Anses, 2018). In 2019, the European Union accounted 307,000 premature deaths attributed to chronic exposure to fine particulate matter (EEA, 2021c). In Europe, the situation is urgent and actions must be taken to encounter the negative externalities of these pollutants. Actually, it is estimated that 178,000 of these premature

deaths could have been avoided if all the European Union members had respected the recommended values of the WHO (EEA, 2022c).

Nevertheless, research on health impacts is undergoing new developments that could prove to be very instructive in terms of guiding public policy. Indeed, whereas until now the health impact of fine particles has been assessed according to their mass, recent research seeks to assess the health impact of fine particles according to their oxidative potential. Oxidative potential refers to the oxidant/anti-oxidant imbalance that the air pollutant causes which damages the human cells and tissues, for instance in the respiratory system increasing the risks of cardiovascular and pulmonary diseases. This oxidative potential depends on the chemical composition of the particles and therefore on their emission sector. Indeed, a fine particle from a vehicle's brakes does not have the same chemical content as a particle from a wood-burning stove, and it is likely that these two particles do not have the same physiological impact on the body either. This research may make it possible to assess the harmfulness of particles according to their area of emission. Weber et al. (2021) identify road traffic as the first daily contributor to higher oxidative potential of fine particles exposure.

These negative environmental and health consequences are translated into significant economic losses. Economists have quantified the health costs caused by poor air quality and related to premature death, the medical treatment or the lost working days. The report of van Essen et al. (2018) shows that air pollution caused by road transport cost in 2016 for the European Union between €67 and 80 billion. WHO (2022) and Delft (2020) underline the role that changes in the individual transportation practices and urban policies could generate on these costs.

Beyond the mentioned externalities, encouraging modal shift from the car to active mobility (eg. public transport, cycling, walking) reduces sedentarity that characterises now the life in high-income countries. Sedentarity or lack of physical activity is usually defined as not meeting the current public health recommendations of at least doing 150 minutes of moderate-intensity physical activity, or 75 minutes of vigorous-intensity physical activity per week (Guthold et al., 2018). WHO (2002a) considers physical inactivity to be the second main risk factor responsible for the deterioration of health in these countries. Indeed, Katzmarzyk et al. (2022) estimated that the physical inactivity prevalence is the highest in higher-income countries (around 37%). They also attributed 7% for all-cause deaths in 168 countries (with low, middle and high income) to sedentarity. Thus, choosing an active mode is an innovative approach to integrate physical activity into individuals' everyday lives (Dons et al., 2015).

The potential for active modes such as cycling or walking to alleviate mortality and morbidity are now well established. The meta-analysis of Hamer and Chida

(2008) identified a positive relation between walking and reduction of cardiovascular disease and all-cause premature mortality. Besides, Bouscasse et al. (2022a) showed that modal shift towards active modes could generate health benefits related to physical activity that may be higher than health benefits from air pollution reduction. Barban et al. (2022) also assessed the health benefits of physical activity thanks to active mobility in the negaWatt scenario.[4] They showed that increases in walking and cycling volumes would prevent 9,797 annual premature deaths in 2045 in France (which corresponds to a three-month increase of life expectancy in the general population). These health gains would generate €34 billion of economic benefits from 2045 onwards.

0.1.2 Impacts of current public air quality improvement measures

Encountering the negative externalities of air pollution caused by the extended use of the private vehicle is a shared responsibility between the government and the citizens. This statement has been supported by previous studies (Dugast et al., 2019; Lanzini and Khan, 2017): the public authorities should design more efficient, fair and acceptable measures and the citizens are no longer passive receivers of these measures but contribute to successfully achieving the measures' objectives through active individual engagement.

National and local public authorities are in fact subject of international pressure to respect emission guidelines in order to protect the environment and the population health. In the European context, the European Union has defined standards for key sources of pollution to be respected by its members[5] and that is included in the National Emissions reduction Commitments (NEC) Directive (European Commission, 2016). This directive sets national reduction commitments for five main air pollutants (SO_2, NO_x, $NMVOC$, NH_3 and $PM_{2.5}$). Commitments are made by the European member countries who are required to monitor and report the emissions and implement national and local measures to meet emission thresholds. Non-compliance with these commitments leads to sanctions for the countries concerned. In 2019, France having exceeded the NO_x emission thresholds in twelve agglomerations, among which Paris, Lyon, Marseille and Grenoble, was subject to such a sanction by the Court of Justice of the European Union.[6] These exceedances are mainly due to emissions from the road transport sector (Citepa, 2020a).

[4]Since 2003, the negaWatt association develops energy transition scenarios for metropolitan France. Barban et al. (2022) assess the negaWatt scenario of increases of walking and cycling (classical and electric bikes) distances of +11% and +612%, respectively, over the 2020-50 period.

[5]https://environment.ec.europa.eu/topics/air$_en$

[6]https://curia.europa.eu/juris/document/document.jsf?docid=219452doclang=fr

These directives contributed to reducing the emissions. For instance, there was a 42% reduction in the emissions of NO_x and 29% reduction for $PM_{2.5}$ emissions between 2010 and 2019 (EEA, 2021b). Despite such emissions reductions, the situation is still critical: large shares of the European population are still exposed to highly concentrated air with pollutants. This is due not only to the high emissions but also to the discrepancy between the current European emissions standards and the scientific evidences about the negative health impact of these emissions. The WHO guideline values, set to protect health, are more restrictive than those of the politically agreed European emissions standards (EEA, 2021a). For example, when following the WHO emissions guidelines, in 2020, there was 96% of the European urban population who were exposed to concentrations of $PM_{2.5}$ above the WHO guideline of $5\mu g/m^3$ compared to only 1% of the urban population above the European Union annual limit value of $25\mu g/m^3$. Outside of the European Union, the United States better respected the WHO guidelines by defining more restrictive political guidelines than the ones in the European Union (known as the National Ambient Air Quality Standards)[7]. For instance, they set in 2020 the annual limit value for $PM_{2.5}$ at $12\mu g/m^3$. Building policies that better respect the health guidelines is essential to guarantee the heath of the population and the members of the European Union should follow the steps of the United States.

Further efforts are being implemented by the policymakers to achieve a healthier air quality. The European Commission actually set a new group of environmental goals such as the European Green Deal's Zero Pollution Action Plan (European Commission, 2021) aiming to improve air quality by specifically reducing emissions of $PM_{2.5}$ in order to reduce, by 2030, the number of premature deaths caused by air pollution by 55%. The European Commission identifies transport and mobility sector[8] as a key sector on which measures should be applied to respect the NEC Directive.

Indeed, in the field of transportation there is an increasing number of public measures restricting the circulation of the most polluting vehicles and encouraging modal shift to active mobility (eg. public transport, bicycle, walking). We identify four main categories of measures: 1) infrastructure, 2) pricing , 3) regulations and 4) information and awareness.

First, measures targeting the infrastructure improvement include building more cycling paths or extending the public transport network (Interreg Europe, 2019). Second, taxing polluting cars [9] and free public transport (Cats et al., 2017) are examples of efficient pricing measures. Third, public regulations could influence dif-

[7] https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm

[8] https://environment.ec.europa.eu/topics/air/air-pollution-key-sectors$_e n$

[9] CO_2-based taxation of passenger cars in the European Union: https://www.acea.auto/fact/overview-co2-based-motor-vehicle-taxes-in-the-european-union/

ferent sectors from the industrial sector, to encourage production and technological developments of less polluting vehicles like hybrid or electric cars (Stratégie, 2018), to the urban planning sector, defining exclusively pedestrian zones (Millet, 2008) or Low Emission Zones (LEZ) restricting the circulation of polluting cars in populated areas (ADEME, 2020).

The measure of LEZs has been gaining popularity in the last decade in Europe and specifically in France. Élisabeth Borne, previous minister of ecological and solidarity transition, expressed her confidence in LEZs to ensure compliance with the emissions standards and ensuring safe air quality (Mandard, 2019). LEZ consists of progressively restricting the circulation of polluting vehicles, in defined zones, based on their Crit'Air stickers. These stickers define six categories from 1 for least polluting to 6 for most polluting considering the type of energy used and the year of circulation (See the classification of the stickers in figure A.1 in appendix A.1). Paris was the first agglomeration in France to implement LEZs. Its objective is to ban all diesel vehicles by 2024. Other agglomerations like Strasbourg, Lyon or Grenoble, are progressively introducing LEZs in respect to The Climate and Resilience Act (loi Climat et Résilience). This act calls for the establishment of LEZs in urban areas with more than 150,000 inhabitants by the end of 2024. Previous implementations of the LEZ measure across Europe (eg. Sweden, Germany, Spain, Italy) have demonstrated its efficacy as a public measure. Twenty ex-post studies (i.e evaluating the consequences of LEZ after their implementation) show reductions in concentration of NO_x, $PM_{2.5}$ and PM_{10}. These emissions reductions decrease the number of premature deaths caused by exposure to poor air quality (ADEME, 2020).

Despite the proven positive consequences of these three categories of measures on the air quality, they still have shortcomings. For instance, encouraging the use of electric cars reduces the pollutant emissions, however, the tire frictions on the road and the car brakes still emit significant levels of fine particles[10]. Besides, public authorities usually combine different measures like implementing LEZ and as an accompanying measure providing better public transportation service. This makes these measures generally costly to implement since they require large investments to build new cycling paths, provide more buses and tramways or create parking lots away from city centers (eg. Park&Ride).

Regardless of these costly measures, there is no guarantee that the targeted population is going to comply and make modal shift to active mobility. The lack of motivation, difficulties in disrupting a strong habit of using the car or having a low environmental concern, are examples of individual characteristics that may prevent

[10]Ademe report "Emissions des Véhicules routiers - Les particules hors échappement": https://librairie.ademe.fr/air-et-bruit/5384-emissions-des-vehicules-routiers-les-particules-hors-echappement.html

the modal shift. Thus technological development and improved infrastructure are insufficient and should be accompanied with individual behavioural change to active mobility. To ensure higher engagement and sustainable behavioural change, public authorities are increasingly using measures from the fourth category of our typology (i.e. information and awareness). This category include behavioural measures that are directed on a target population to generate behavioural change. Public authorities are increasingly using such measures in combination with more classical measures from the three previous categories. For example, public authorities use communication campaigns to spread information about the consequences (positive or negative) of individual mobility practices (Markvica et al., 2020; Bouscasse et al., 2022b) which has demonstrated to have a significant effect on mobility practices. Designing such measures is based on behavioural insights from economic, psychological or sociological studies. These studies provide a better understanding of the individual determinants of modal shift, allowing public authorities to target the most influential levers. The present thesis contributes in enriching these insights by its interest in studying a number of individual determinants underlying the intention to modal shift.

0.1.3 Understanding the determinants of individual mobility practices

The determinants of mobility and modal shift behaviour are numerous and multidimensional. Some will slow down the modal shift towards active mobility, others will favour it. A better understanding of these determinants will allow public policies to target the right levers and to adopt policies that are effective not only from an environmental point of view, but also from a social and economic one. Aware of this multidimensionality, De Witte et al. (2013) adopted a multidisciplinary approach defining modal choice as "the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors". Their review of 76 modal choice papers defines four categories of determinants including: 1) the socio-demographic indicators like age, gender, income or education; 2) the spacial indicators like density[11], frequency of public transport or parking availability; 3) the journey characteristic indicators like travel distance, time or motive and 4) the socio-psychological indicators like lifestyle, habits and perceptions. The De Witte et al. (2013)'s review allowed a classification of the most influential and represented determinants of modal choice in the literature presented in figure 2. According to this classification, a first group of determinants is rarely studied

[11]Density is defined as the ratio $\frac{inhabitants}{builtuparea}$.

and rarely found to have a significant effect on mobility practices. This category includes determinants like lifestyle or perceptions. This means that these determinants should be further investigated to confirm their low impact. If they prove to be insignificant, not considering these variables in the public policies measures is appropriate. In a second group, variables are rarely studied but frequently found significant. In this category, we can find habits or parking availability. This means that these determinants should also be further assessed to identify ways to use them as public policy levers. Third, variables like gender or employment are often studied but rarely found significant. Thus, such determinants should be less considered in the design of the transport public policies. Lastly, there are the variables frequently studied and usually found significant. For example, the availability of a car is taken into account in almost half of the articles reviewed and is found to have a very significant effect on modal choice. Income, household composition, age and population density are in this category as well. Given their significant influence, these variables must necessarily be considered by the public authorities.

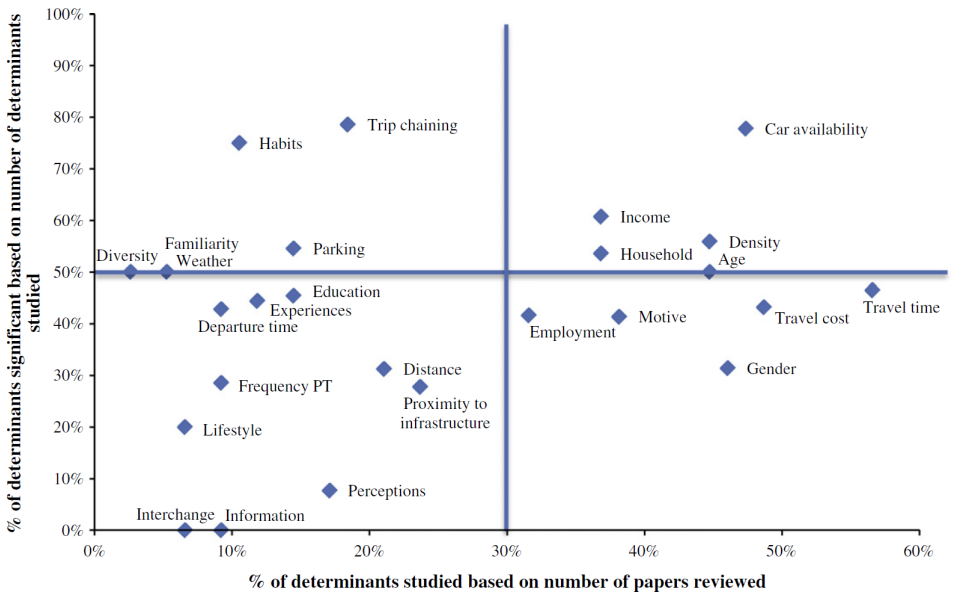

Figure 2: Classification of modal choice determinants from the review of De Witte et al. (2013)

Focusing on the study of specific determinants allowing modal shifting, Javaid et al. (2020) conducted a meta-analysis of 75 review papers on the adoption of active mobility (called, low-carbon transport modes). They also underline the importance of using a multidisciplinary approach in the study of mobility. Javaid et al. (2020) contribute to the scarce inter-disciplinary literature by including review articles from psychology, economics, sociology and urban planning in their meta-analysis. The literature review leads them to classify the modal shift determinants into three main categories: 1) material and psychological individual factors like attitudes, be-

liefs and habits; 2) social factors like social influence or subjective norms; and 3) infrastructure-related factors like land-use planning or transport system quality besides to time and monetary costs.

Javaid et al. (2020) summarise their results in figure 3 presenting the size of influence of the most significant determinants. In the first category (i.e. individual factors), key factors are almost the same across the different modes except for walking. Habits and beliefs are the main factors, followed by attitudes. A higher perceived behavioural control[12] about the mode of transport and previous use of that mode, increases the likelihood of choosing it. In the second category (i.e. social factors), the social influence is the most important variable determining modal shift. This refers to the fact that the probability of mode to be chosen increases if the person's entourage uses the same mode. The meta-analysis of Javaid et al. (2020) underlines the stronger effect of the third category of determinants (i.e. infrastructure-related factors) compared to the previous two categories. They found that having cycling paths, pedestrian zones, accessible transportation system and short trip distances are examples of factors that ensure larger modal shift towards active mobility. Lastly, the authors identified a significant role of costs in terms of time or money as a determinant that could interact with the previously mentioned determinants of modal shifting. For instance, the implementation of a tax on fuel makes the car less attractive and if a good public transport system is available there will most likely be a high modal shift from the car to public transport.

The meta-analysis of Javaid et al. (2020) underlines a strong correlation between the individual factors and the individual intentions to modal shift rather than between the individual factors and the reported actual behaviour. Thus, there is an intention-behaviour gap. This gap is the result of individuals stating intentions different from their real behaviour. This gap is highlighted in the study of pro-social or pro-environmental behaviours like modal shifting to active mobility. European Commission (2020) found that 62% of the French population state that they are ready to switch to less polluting and more active modes. However, beyond these declared intentions real engagement in such practices is still low. Actually, according to the same report, 66% of the population use the car for their daily travels compared to significantly lower shares of usual walkers, public transport users and cyclists. Thus, there is a divergence between the declarative surveys and actual behaviour. There is a growing literature investigating ways to understand and reduce the gap (Sheeran and Webb, 2016). Javaid et al. (2020) mention that some infrastructure factors can address specific aspects of this gap in certain conditions.

These literature reviews also point out that some of the social and individual fac-

[12]It reflects the individual's beliefs about his ability of doing the behaviour and the degree of control that he has over the behaviour.

tors would require further research to better understand their role in modal choice and modal shift particularly towards active modes. Thus, there is still room for additional investigations on variables such as perceptions, attitudes, habits and motivations to modal shift, especially for walking and cycling.

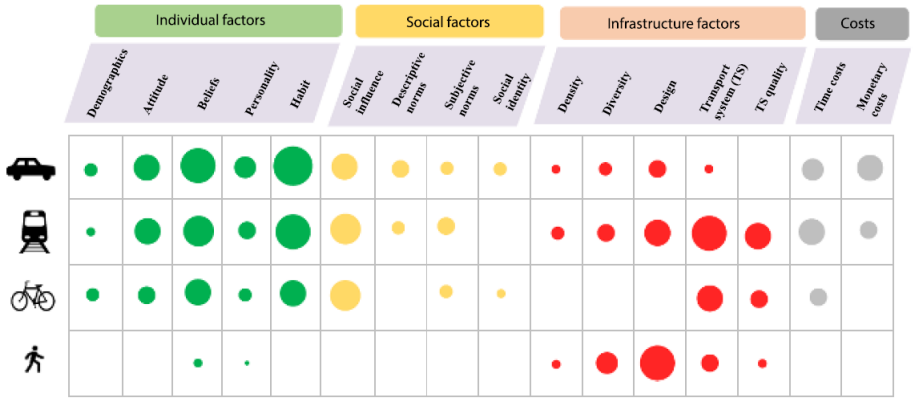

Figure 3: Classification of modal shift determinants* from the review of Javaid et al. (2020)

*Size of the circle indicates the importance of the factor to the related transport mode based on the relationship strength ratings in the review findings. Empty boxes represent lack of supporting evidence

In addition to the diversity of determinants of modal choice and modal shift, the development and implementation of transport behaviour studies presents the challenge of observing and measuring the actual transport behaviour of individuals. Indeed, this is costly, raises confidentiality issues, can be perceived as intrusive and requires observations that take into account many variables (sociodemographic determinants, sequence of activities, logistical family constraints...). Thus, researchers have been using measures of stated individual intentions as a proxy of the individual behaviour. This is true for a significant share of articles included in the previously reviewed studies of Javaid et al. (2020) or De Witte et al. (2013). They actually justify using measures of intentions relying on the Theory of Planned Behaviour (TPB) (Ajzen, 1991) to understand modal choice and modal shift determinants. This is possible since this theory states that intentions are the closest antecedent of behaviour. These intentions are defined as the amount of effort the person is willing to exert to perform the behaviour and they are the result of the combination of three elements: 1) *attitude toward the behaviour*, referring to the beliefs that the individual has about the positive or negative consequences of carrying out the behaviour, 2) *subjective norms*, which reflect the individual's perceived social pressure, and 3) *perceived behavioural control*, which depends on the individual's beliefs about the degree of control that he/she has over the behaviour.

As modal shift to active mobility can be seen as both a pro-environmental be-

haviour and a means to engage in physical activity, and given the variety of its determinants, broader theoretical perspectives should be considered to understand the role of motivation in the behaviour. The Self-Determination Theory (SDT) (Deci and Ryan, 1980) provides a widely used theoretical framework for studying the motivations underlying the adoption of healthier practices (such as physical activity). Thus, the SDT is applicable to the study of active mobility. Thiermann and Sheate (2020) consider this theory "has not been on the radar of mainstream environmental psychologists" and, we think, even less for environmental economists. The SDT defines a continuum of motivations ranging from self-determined motivation derived from internal factors of interest, pleasure, or satisfaction to non-selfdetermined motivation typically derived from external motivations distinct from the behaviour itself, such as a sense of social pressure of guilt or shame. The use of such a theory in transportation studies would bring a new perspective to the discipline in explaining the determinants motivating modal shift.

According to Javaid et al. (2020), "disciplines differ in their understanding of transport mode choice[...]While, none of these perspectives claims completeness, or exclusivity, due to disciplinary boundaries these different perspectives end up looking at pieces of a puzzle rather than providing the complete picture.". Thus, collaborations between disciplines are necessary to have a better understanding of the mobility determinants. Other reviews studying active mobility (Koszowski et al., 2019; Sallis et al., 2004) have also demonstrated the utility of such collaborations by creating bridges between transport planning, urban planning and public health. This would consequently allow formulating coherent political recommendations between sectors which in turn would guarantee political governance with aligned objectives.

To conclude, the presented elements in this section suggest that only relying on the public authorities efforts is insufficient to attain a more livable future. The individuals' engagement in pro-social or pro-environmental behaviours such as active mobility is essential to have cleaner air and better health for oneself and for everybody else. This context begs for a better understanding of the most influential determinants to be used as levers for promoting active mobility. The review of these determinants show the potential for using the individual psychological factors and information as they prove to be significant for a modal shift. They could also be mobilised at a lower economic cost than infrastructure, and at a lower social cost than pricing or tax policies. Thus, the individual determinants should be further investigated.

0.2 The present Thesis

0.2.1 Research question

This thesis contributes, through economic and psychological theories, to a better understanding of the individual determinants for the adoption of pro-social and pro-environmental behaviours. By focusing on individual mobility practices, we attempt to identify public policy levers to promote active mobility. The study of this behaviour is particularly important given its environmental and health externalities that we previously highlighted. Therefore, the central question of this thesis is: *How could behavioural insights help identifying public policy levers to promote the adoption of active mobility and, more generally, of pro-social or pro-environmental behaviours?*

Following the thesis general structure presented in figure 4, we define four chapters each interested in investigating a group of determinants. We focus on the individual determinants organised in three categories: trip characteristics, socio-demographic factors and psychological factors. We suppose that the combination of these determinants allows defining intentions which are then translated into real behaviour. We also assume that there are interactions between public policies and the individual determinants. On the one hand, public policies act on these determinants, the intentions and the behaviour, and on the other hand, behavioural insights about the determinants could be included in the design of these policies.

Throughout this thesis, our interest is to primarily explain intentions to modal shift rather than actual behaviour. This is first justified by the difficulty of capturing actual transportation behaviour through declarative surveys. Second, it is motivated by the general use of intention measures in previous studies of individual mobility (Gardner et al., 2020; Javaid et al., 2020; Hoffmann et al., 2017), making this work comparable to that literature. However, we attempt to get closer to measuring actual pro-social or pro-environmental behaviour through the laboratory experiment implemented in the final chapter of this thesis. Throughout this work, we maintain a multidisciplinary study approach mobilising tools from economics, psychology and health studies.

The first chapter assesses the acceptability of the project of implementing a LEZ in Grenoble restricting the circulation of polluting private vehicles. The second chapter, based on the SDT framework, focuses on the modal shift motivation-intention relationship and studies the role of active mobility habits in this relationship. In the third chapter, based on a discrete choice experiment, the objective is to test the influence of the presentation of information about the morbidity risks of mobility practices on modal shift intentions. Taking a broader perspective than the study of modal shift, the fourth chapter tests public interventions applicable not only to

the transport field but also to any other pro-social or pro-environmental behaviour. A more detailed presentation of these chapters is included in section 0.2.3. For the whole thesis, the Grenoble Metropolis (France) is the field of study with two conducted surveys and an online laboratory experiment.

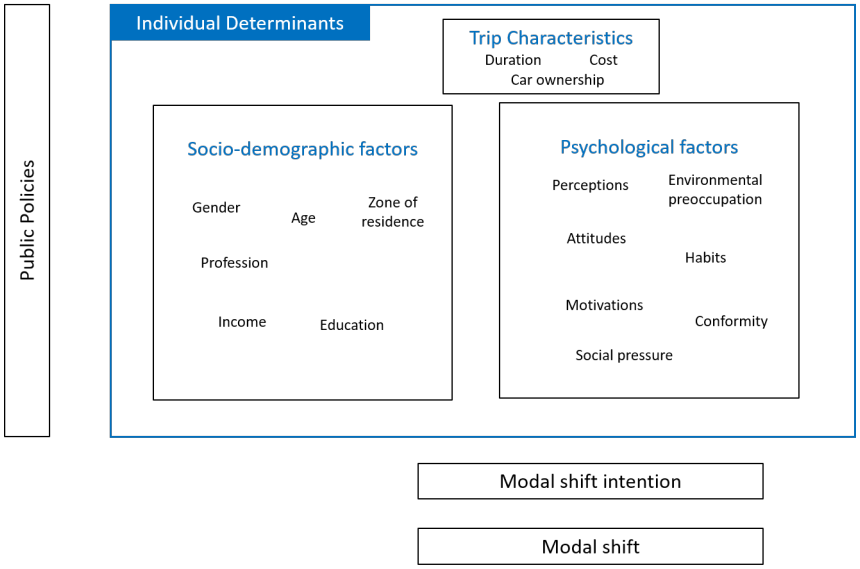

Figure 4: General thesis structure

0.2.2 Study case and funding

We choose the Grenoble Metropolis as a study area. Grenoble is the main city located in Isère department in Auvergne-Rhône-Alpes region south-East of France. The Auvergne-Rhône-Alpes region is the second most populated in France. The Grenoble Metropolis is composed of 49 municipalities with approximately 450,000 inhabitants.[13] We collect data about the residents of Grenoble using three different data collection methods: a phone survey (1,304 participants), an online survey (1,000 participants) and an online laboratory experiment (312 participants). Collecting this significant quantity of data using three different methods is another originality of the present thesis.

The most recent estimation of Santé Publique France (2021a) shows that in France each year nearly 40,000 deaths are attributable to exposure of people aged 30 and over to fine particles. Each year, nearly 4,300 people die prematurely due to pollution in the Auvergne-Rhône-Alpes region (Santé Publique France, 2021b). For Grenoble, it is estimated that every year 145 people die prematurely due to fine particle pollution (out of about 2600 deaths from all causes in the Grenoble Metropolis) (Inserm, 2019).

Despite the general reduction of emitted air pollutants in Isère since 2000 (40%

[13]https://www.insee.fr/fr/statistiques/1285839

and 48% reduction for, respectively, $PM_{2.5}$ and NO_x), it is still characterised with poor air quality (ATMO, 2019). Modal shift to active mobility has been demonstrated to be a valid strategy to avoid a significant share of the premature deaths in Grenoble (Mathy et al., 2022) thanks to the amelioration of air quality and the gained physical activity.

This thesis is funded by the Grenoble IDEX, as part of a large interdisciplinary project called MobilAir[14]. MobilAir aims to identify specific measures to significantly reduce air pollution in cities and its impacts. A part of this thesis is also built on data collected from a companion project of MobilAir: the QAMECS-SHS project (Qualité de l'air dans l'agglomération grenobloise: Évaluation de l'environnement, du comportement et de la santé) that is financed by Ademe (Agence de la transition écologique) and La Metro (Grenoble-Alpes Métropole). The following two paragraphs briefly describe the two projects and their objectives.

The MobilAir project (2018-2021) - Building on the multidisciplinary richness of the Grenoble campus, MobilAir develops an integrated approach in the Grenoble urban area. It gathers researchers from local laboratories of different disciplines working on one or more aspects of air pollution: transport, environmental and health economists (GAEL), sociologists, behavioural psychologists (SENS), geographers (PACTE), epidemiologists (IAB), atmospheric modellers (ATMO-AuRA, IGE and LEGI), transport and land use modellers (LJK). MobilAir aims to develop methods and tools that can be replicated in other cities in France or abroad. Specifically, it has three main objectives corresponding to three Working Packages (WP): WP1. A better comprehension of the population's exposure to pollution; WP2. A detailed understanding of the determinants of mobility behaviour and WP3. Support for public decision-making. The present thesis is part of the WP2.

The QAMECS-SHS project (2019-2022) - It is an interdisciplinary project that combines economics, psychology and sociology to, first, evaluate the individual's representations, perceptions, knowledge and practices in terms of transportation (and heating) under air quality improvement measures. Second, it examines how psychological constructs could interact between each other in orienting the intentions of using alternative modes to the private vehicle. Finally, it assesses if the impact of transport modes on individual and public health, could be an individual determinant of transport mode choice. To respond to these questions two representative samples from the population of the Grenoble Metropolitan Area were generated to conduct two surveys: 1) a phone survey, addressing the two first objectives of this

[14]https://mobilair.univ-grenoble-alpes.fr/

project and 2) an online survey composed of a discrete choice experiment addressing the third objective of this project.

0.2.3 Outline of the Thesis

We answer the main research question by defining four sub-questions included in the previously presented thesis structure (i.e. figure 4). Each question is treated in a separate chapter and this section presents the main analyses and results. The findings allow to formulate public recommendations about influential levers to encourage the adoption of pro-social or pro-environmental behaviours.

0.2.3.1 Chapter 1: Determinants of the acceptability of air quality improvement measures - The case of LEZ in Grenoble

LEZs are among the most emblematic measures to reduce emissions resulting from road traffic. They aim to limit the circulation of the most polluting vehicles in urban zones with high population exposure to pollution. The introduction of LEZs has become mandatory in urban areas in France with pollutant concentration and exposure thresholds that exceed the limit values. The Climate and Resilience Act (La loi Climat et Résilience) requires the establishment of LEZs in urban areas with more than 150,000 inhabitants by the end of 2024.

The introduction of public measures to create a modal shift towards active mobility could have consequences not only on the individual's transportation practices but also on his day-to-day activities. However, few studies evaluate the public acceptability of LEZs measure before introducing them. Indeed, acceptability is an essential element in ensuring the success of a public measure. This idea has been confirmed in previous studies (Gu et al., 2018; Jagers et al., 2017; Rye and Ison, 2005) that have evaluated the acceptability of other air quality improvement measures (e.g., congestion policies, pricing policies). In France, existing studies on LEZs are mainly conducted in Paris estimating environmental and health impacts based on hypothetical scenarios with less emphasis on analysing the acceptability of this measure (eg. Poulhès and Proulhac, 2021; Host et al., 2020).

In this chapter, we contribute to this literature by using the Grenoble LEZ project as a case study. We attempt to answer the following question: *What are the determinants of the residents of Grenoble Metropolis acceptability to the LEZ as a measure of air quality improvement?* This type of evaluation allows public authorities to better study the feasibility of the measure, to know the expectations of the target population, the possible obstacles to the adoption of the encouraged behaviour and, consequently, to adapt the planned accompanying policies to ensure

greater economic and social efficiency. Thus, the objective of this chapter was to present an ex-ante evaluation (i.e., before the introduction of the measure) of the acceptability of the LEZ in Grenoble in order to help the local authorities (La Metro) to implement the measure effectively. We were actually part of the scientific committee[15] for the evaluation of the implementation of this measure. Some results of this chapter were presented to services and elected representatives of the Metropolis in order to assist local public authorities.

To answer this research question, we assess and explain the acceptability of a sample of 1,304 Grenoble residents using data collected through a phone survey in 2019. We use inferential statistics and binary logit regression on the calibrated data to compare characteristics of supporters versus opponents determining their levels of acceptability. Determinants of acceptability are organised into three categories: 1) socio-demographic factors such as gender or age, 2) travel-related characteristics such as Crit'Air sticker ownership, and 3) psychological factors such as attitudes and perceptions. The variables of interest and the chapter structure are presented in figure 5 (variables of interest colored in green).

The results show that the acceptability of the implementation of the LEZ is relatively high. Analyses comparing the characteristics of supporters with those of opponents show little influence of socio-demographic determinants on acceptability. Travel-related characteristics have more influence, with lower acceptability expressed by those with more polluting vehicles and lower active mobility habits. However, the most important determinants of acceptability appear to be individual attitudes and perceptions. In fact, participants who are more concerned about the environment and who have positive attitudes and perceptions of this measure express greater acceptability for its implementation.

We find a strong potential for modal shift towards active mobility expressed by our participants in case this measure is implemented, especially for commuting. In addition, by providing suggestions for accompanying measures to increase the acceptability of LEZs, participants strongly encourage the improvement of public transport services in terms of economic, physical and social accessibility.

[15]Sandrine Mathy, Hélène Bouscasse and myself.

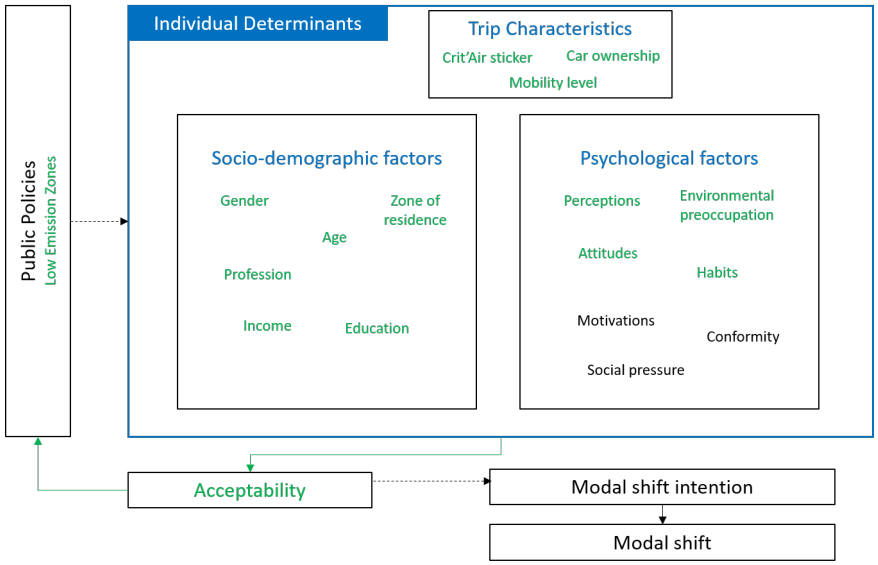

Figure 5: Structure of chapter 1

0.2.3.2 Chapter 2: What is the role of active mobility habits in the relationship of selfdetermined and non-selfdetermined motivations with modal shift intentions? A mediation analysis

In the second chapter, intention is defined as an expression of the amount of effort a person is willing to put into a socially desirable behaviour. This effort depends on individual motivation, which is different from one individual to another (Thøgersen, 2005). Thus, the study of the motivation-intention relationship is essential to propose measures that effectively enable modal shift (Thiermann and Sheate, 2020). To study the motivations underlying the adoption of active mobility, we mobilise the SDT (Deci and Ryan, 1980), which seems relevant in this context. Previous studies have demonstrated through this theory the significant relationship between motivation and intentions (eg. Hagger and Chatzisarantis, 2009) but not in the context of mobility studies. We also introduce habits into the studied relationship due to its impact on current mobility practices and modal shift intentions (Eriksson et al., 2008).

By considering the choice of alternatives to the car as a way to reduce pollutant emissions and to engage in physical activity, we contribute to the transportation literature by investigating the motivation-intention relationship as well as the role of active mobility habits in this relationship. We try to answer the following question: *What is the role of active mobility habits in the relationship of self-determined and non-selfdetermined motivations with modal shift intentions?*

To answer this question, we construct and test a hypothetical motivational process of modal shift intentions. We distinguish between self-determined motivation (SDM), referring to feelings of pleasure or belief in the usefulness and importance

of modal shift, from non-self-determined motivation (NSDM) including social pressure or fear of being criticised or judged. The variables of interest and the chapter structure are presented in figure 6 (variables of interest colored in orange).

Mediation analysis using structural equation modelling shows that SDM is positively correlated with higher active mobility habits and modal shift intentions. The effect of this type of motivation on intentions by considering habits is only indirect, confirming the strong influence of mobility habits on behaviour change. On the contrary, NSDM motivation is negatively correlated with active mobility habits and does not significantly influence modal shift intentions.

These results indicate to public authorities the importance of taking habits into account when designing behaviour change interventions. The strong effect identified for habits suggests the need to find ways to disrupt unwanted habits and to promote the construction of habits of the desired behaviour (here, active mobility). This work has provided more clarity on how desirable habits are influenced by motivations. In the case of active mobility, they are strongly linked to the internal beliefs and attitudes of the individual, whereas external (social or institutional) pressure from the individual's environment could play a counterproductive role. In this case, specific public measures allowing for example the individual to feel more in control of his decisions and to have a better perceived behavioural control would be more effective than those based on the highlighting of social norms.

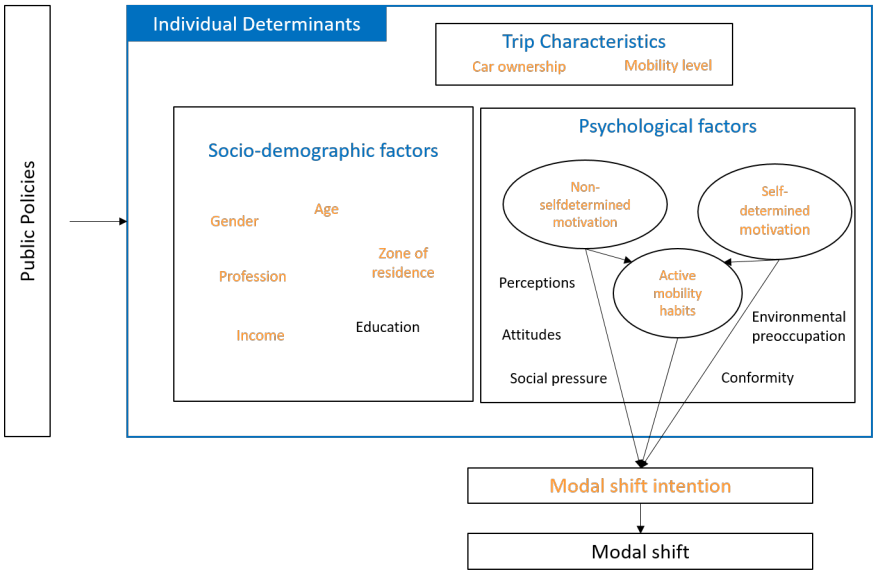

Figure 6: Structure of chapter 2

0.2.3.3 Chapter 3: Is the impact of transport modes on health an individual determinant of transport mode choice?

In this chapter, we focus on the study of the influence of health risk perception on modal shift intentions towards active mobility. Active mobility generates two types of health co-benefits. Firstly, there is a reduction in public health risks related to improved air quality. Second, there is a reduction in individual health risks associated with increased physical activity through active mobility.

In the literature, few studies have evaluated the impact of providing information on health risks as a lever to generate modal shift (Sottile et al., 2015b; Meloni et al., 2013). To the best of our knowledge, no previous study has assessed the consequences of providing health information by separating the individual health impact from the one related to general population. We therefore attempt to answer the following question: *Is the impact of transport modes on health an individual determinant of transport mode choice?*

Following the structure of the chapter presented in figure 7 (variables of interest colored in pink), we answer the research question by conducting an online stated preference survey (a discrete choice experiment, DCE) in 2019. The final sample includes 792 residents of the Grenoble metropolis. The DCE offered the possibility to choose a mode among three alternatives (car, public transport and bicycle)[16] taking into account classical determinants (travel time and cost) and health determinants (individual and public health risks).

One of the original features of our DCE is that it is based on quantified health risks. The first health risk refers to the risk of developing cardiovascular diseases as a function of exposure to air pollution induced by the choice of transport mode. The second risk is the risk of developing cardiovascular disease as a function of the physical activity induced by the choice of active mode. Due to the lack of familiarity of individuals with these health attributes, we facilitate their understanding based on the medical literature (Fagerlin et al., 2011) by using pictograms. Besides, we report additional information on the share of the population already adopting an active mode (50%, 75% and 90%) to test for a conformity effect on modal shift intentions.

We model the utility associated with each mode of transport within the framework of the discrete choice model (McFadden, 1974) comprising a vector of individual variables and a vector of alternative-specific variables. As the health risks can be perceived differently by individuals (considered as presented, under-estimated or over-estimated), we define them as a power function (Yaari, 1987; Bouscasse and de Lapparent, 2020).

[16] A sample of 211 participants was also recruited to respond to a DCE including the walking alternative for distances of less than three kilometres.

The results of the multinomial and mixed logit models show that both individual and public health risk information significantly influence participants' probability to modal shift. This means that for both pieces of information, the higher the reduction in cardiovascular disease risk, the higher the probability of choosing an active mode. We also identify a conformity effect which results in a more significant effect of the public risk information than the individual risk effect when a larger share (75% and 90%) of the population already adopts an alternative mode. However, when communicating health information, simply mentioning the possibility of reducing health risks seems to have more influence on mobility preferences than insisting on the exact rate of this reduction.

These results indicate to public authorities the usefulness of building communication campaigns presenting individual and public health impacts to encourage modal shift. The information communicated must be accessible and our work identifies that a simple presentation of a potential health risk reduction is sufficient to create behavioural change.

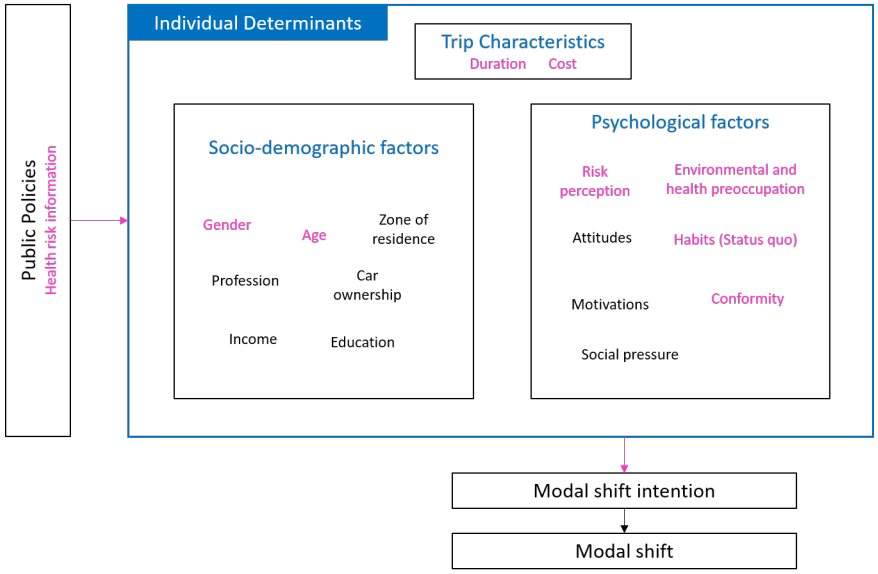

Figure 7: Structure of chapter 3

0.2.3.4 Chapter 4: How to go from intentions to actions to orient individuals to adopt socially desirable behaviours? A laboratory experiment

The fourth and final chapter takes a step back from modal shift issues. It deals more generally with pro-social or pro-environmental behaviours. We assume that the adoption of these behaviours is limited by either weak real intentions or the fact that, even with strong intentions, one encounters difficulties in translating them into real behaviour. This results in a gap between intentions and behaviour. Therefore,

if we want to encourage the adoption of socially desirable behaviours, we suppose that we either need to 1) reinforce intentions in order to increase the likelihood that the behaviour will be adopted, or 2) to directly influence the behaviour by trying to reduce the gap.

Existing interventions are mainly based on nudges that impact behaviour by harnessing cognitive biases (eg. Ghesla et al., 2019). These interventions are less focused on influencing intentions. As intentions are not measured beforehand, the actual effect of nudge on the gap between intentions and behaviour is unknown. The few applications on intentions generally fail to significantly encourage the adoption of desirable behaviour (eg. Gaudeul and Kaczmarek, 2017). We believe that a valid justification for this failure is to neglect the process underlying the formation of intentions and behaviour. Depending on the targeted variable, intention or behaviour, it is necessary to choose an intervention that is appropriate with the variable's characteristics. Considering Kahneman (2003)'s human reasoning process, behaviour and its original intentions are the results of two distinct reasoning systems: intentions come from the activation of System 2 since they are the result of a conscious and deliberate thought process. This means that an intervention that effectively influences this process could be effective. Whereas behaviour is a manifestation of a cognitive shortcut with a rapid and subconscious thinking process activated by System 1. Thus, an intervention exploiting this faster process would be more appropriate.

The aim of both interventions is to improve social well-being. However, it is essential to consider the well-being and emotions of the individual to ensure better acceptability of the intervention and, therefore, its success. In the literature, there are few studies that assess the impact of tested interventions on participants' emotions. Thunström (2019) is one of the few who considered that a menu labelling nudge intervention can generate an emotional cost, also called an "emotional tax".

To our knowledge, no previous work has ever compared interventions playing on intentions or behaviour in the same context with the aim of assessing their effects on the adoption of socially desirable behaviour and emotions. All these elements lead to the question: *In order to promote the adoption of socially desirable behaviour, should we influence intentions through cognitive effort (System 2) or behaviour through cognitive bias (System 1)?*

This chapter follows the structure presented in figure 8 (variables of interest colored in purple). We answer the research question by conducting an online laboratory experiment following a between-within design with a charity game (Eckel and Grossman, 1996). The game consisted of participants deciding twice how much to donate to a charity, between €0 and €10, with an initial endowment of €10 each time. The final payment for the participants was the remaining amount of a randomly chosen

donation from the two previously defined donations plus a fixed participation fee of €5. The final sample consisted of 312 residents of Grenoble recruited using the internal contact database of the GAEL laboratory. These participants were divided into two treatment groups and a control group: 106 in the control group, 113 in the learning treatment and 93 in the default nudge treatment.

This experiment allowed us to measure intentions and donations twice, by introducing the intervention on the first measure and assessing its long-term effect on the second measure. We attempted to increase donation intentions by applying a cognitive effort task on this measure, called a learning intervention. It consisted of presenting additional information about the proposed charities, testing this information with a quiz, and giving subjects time to express their opinions about the activities of the charities and the usefulness of their donations. The second intervention is the default nudge intervention, which plays on the status quo bias to influence donation behaviour. We present subjects with the option of donating up to €10 by performing a slider task with a default option. The default option is to present 50 sliders, each equivalent to 20 cents, initially positioned to the right. If the subject does not drag to the left the number of sliders equivalent to the desired donation amount, a donation of €10 is automatically made.

Based on the assumption that we could be in a case of either a gap between intentions and donations or no gap, we compare the effects of the interventions to the control group. The results show the usefulness of both interventions with positive effects on intentions and donations. But the short-term effect suggests that improvements should be undertaken to ensure a positive long-term effect. The learning intervention did confirm that the short-term reinforcement of intentions works, but it was not possible to sustain this effect in the long term. Thus, the increase in intentions to donate did not translate into an actual increase in donations. In contrast, the default nudge intervention had a significant behavioural effect, but surprisingly small compared to the literature, on the increase in donations and a significant effect on the level of attrition which resulted in a selection effect. Regarding the effects of the two interventions on emotions, we find that negative emotions decrease significantly between the two measurement times (before and after donation), suggesting a kind of satisfaction effect called "warm glow effect". However, when comparing this effect between treatments, we found that after the donation, positive emotions are expressed more in the learning treatment than in the default nudge treatment.

These results contribute to the literature on behavioural interventions, providing interesting insights for public authorities in the implementation of public interventions. In fact, we confirm the difficulty of influencing individual intentions as a real issue in generating behavioural change. The results concerning the effect of these interventions on emotions could also be exploited to maintain the positive effects

of the interventions. The fact that giving maintains positive emotions and reduces negative emotions could be used as an additional incentive to encourage the adoption of socially desirable behaviour. Public authorities could use this positive effect on individual and public welfare. This result is in line with the recommendation of Butts et al. (2019) and Noetel et al. (2020) who suggest highlighting the pleasure and emotional rewards that giving generates to effectively encourage more giving.

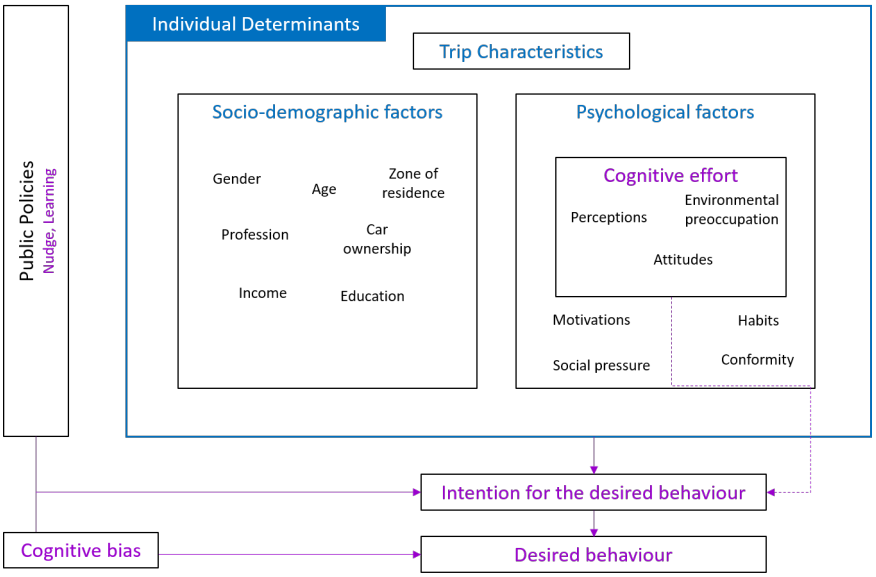

Figure 8: Structure of chapter 4

Chapter 1

Determinants of the acceptability of air quality improvement measures: The case of LEZ in Grenoble

Jointly done with Hélène Bouscasse [1] , Sandrine Mathy [2] and Carole Treibich [2]

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Abstract

In response to the challenges of air pollution and the associated health risks, increasingly more measures are aimed at discouraging the use of cars. One of them is the implementation of Low Emission Zones (LEZ). Although their implementation raises many debates, due to the constraints that this measure may induce on the individual daily activities, there is little evaluation of their acceptability and its determinants, notably an ex-ante evaluation before the LEZs are implemented. We contribute to this literature taking Grenoble as a study case. We study the determinants of the acceptability of the residents of Grenoble by analysing original data using bivariate analysis and a binary logit regression. The results show acceptability with lower levels for the individuals that are the most affected by the LEZ. This acceptability is mainly determined by the individual positive attitudes and perceptions for the LEZ and less influenced by the socio-demographic characteristics. We use our results to formulate recommendations for the public authorities.

Keywords: air quality, acceptability, low emission zone, individual transport mode

1.1 Introduction

In Europe, with the expansion of urban areas, 75% of the population lives in cities in 2021.[3] This share is expected to rise to around 84% in 2050.[4]. Despite of the positive economic growth that the development of the urbanisation generates, the growing density of both population and infrastructure highlights its negative externalities on the environment and health. These urban areas are particularly characterised with bad air quality with high concentrations (eg. $PM_{2.5}$, PM_{10}, NO_2). Road traffic is one major contributor to these pollution which in turn deteriorates cardiovascular and respiratory health. In 2017, road transport was responsible of 46% of the non-exhaust emissions of $PM_{2.5}$ in Europe[5]. Actually, in 2020, 96% of the European urban population was exposed to concentrations of fine particulate matter $PM_{2.5}$ above the WHO guideline of $5g/m^3$.[6] WHO (2014) describes poor air quality as "the world's largest single environmental health risk" causing, in 2016 in Europe, around 400 000 premature deaths (Khomenko et al., 2021).

Increasingly ambitious, but sometimes more restrictive, policies have been implemented by public authorities to ameliorate air quality in urban areas and reduce the population exposure. One of them, is the implementation of Low Emission Zones (LEZ). A LEZ is a defined urban area where the access of the most polluting vehicles is banned following standardised vehicles' categorisation according to their pollution level. Such policy allows the reduction of air pollutants emitted by road traffic (Ku et al., 2020, Figure 2), resulting in reduced air pollutant concentrations in the concerned areas and consequently reduce the number of people exposed to concentrations above the recommended values by WHO (2021) with expected health benefits (Host et al., 2020). The restrictive nature of the LEZ also allows to encourage the use of active mobility (Paris, 2022; ADEME, 2020) which in turn increases physical activity.

The first LEZ was implemented in 1996 by Sweden (Ku et al., 2020). Since then, a number of European countries followed the steps of Sweden resulting in more than 250 zone implemented across the European Union nowadays (Moreno, 2020). The first LEZ implemented in France was the one in Paris introduced in 2015, followed by other major cities such as Lyon, Grenoble and Marseille. Until now, the LEZ restrictions were mainly applied on freight transport. But the critical environmental and health context and the political pressure resulted in the progressive introduction of LEZ restricting the circulation of private vehicles. Paris was the first agglomer-

[3] https://www.statista.com/statistics/270860/urbanization-by-continent/

[4] https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation$_en$

[5] https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8

[6] https://www.eea.europa.eu/highlights/vast-majority-of-europes-urban

ation to implement this measure aiming to ban all diesel vehicles by 2024. Other cities like Strasbourg and Grenoble may also progressively ban the diesel cars. This is in respect to The Climate and Resilience Act (loi Climat et Résilience) which calls for the establishment of LEZs in urban areas with more than 150,000 inhabitants by the end of 2024.

Introducing such restrictive public policies strongly influences individual mobility practices and other general day-to-day activities. Thus, it requires a certain level of acceptability from the targeted population to guarantee successfully attaining the measure's objectives. Acceptability is usually defined as the way "an intervention will be received by the target population and the extent to which the new intervention or its components might meet the needs of the target population and organizational setting" (Ayala and Elder, 2011). Thus, not considering the population acceptability ex-ante could even lead to a general rejection and withdrawal of certain ambitious policies. For instance, in France, the crises of the yellow jackets (Gilets jaunes) triggered by the announcement of the increase in the carbon tax in 2018 or the red bonnets (Bonnets rouges) movement in 2013 against a new tax "Ecotaxe" on truck transport are emblematic of this.

Evaluating the acceptability of LEZ is only gaining interest in recent years. Two approaches are possible: 1) either an evaluation of acceptability after the implementation of the measure (ex-post) 2) or prior to its implementation (ex-ante). These two types of evaluation done in different points of time in the implementation process of this measure give interesting but different insights to the public authorities. Carrying out an ex-post evaluation makes it possible to validate or not the achievement of the initial objectives of the public measure, to change the ambition of the measure and to define compensation or accompanying measures. It also gives the public authorities an idea of whether their interventions where appreciated by the targeted population. Whereas an ex-ante evaluation allows for public authorities to be more aware of the feasibility of the project, the expectations of the targeted population, the possible obstacles to adopt the encouraged behaviour and consequently to adapt the planned accompanying policies to guarantee more economic and social efficiency.

The aim of this paper is to contribute to these evaluations by making an ex-ante evaluation of the acceptability of the residents of Grenoble Metropolis (France) for the future project of implementing LEZ restricting the circulation of polluting private vehicles. Through the results of this evaluation we assist local authorities in an efficient implementation of this measure. Thus, we attempt to answer the question: What are the determinants of the acceptability of LEZ in the case of Grenoble?

Answering this question, we use original data collected through a phone survey.

Implementing bivariate analysis and binary logit regression allowed us to find a general acceptability of LEZ with lower levels for the individuals that are the most affected by the circulation restrictions. This acceptability is mainly determined by the individual positive attitudes and perceptions for the LEZ and less influenced by the socio-demographic characteristics.

1.1.1 The LEZ in Grenoble Metropolis

Grenoble Metrpolis is the most populated area in the Isère region of France representing 36% of its population.[7] The metropolis is composed of 49 municipalities with around 450,000 residents among which 158,454 are living in the Grenoble city.

Despite the general reduction of emitted air pollutants in Isère since 2000 (40% and 48% reduction for, respectively, $PM_{2.5}$ and NO_x), it is still characterised with poor air quality and large shares of the population are exposed to highly concentrated air with $PM_{2.5}$ and NO_x (ATMO, 2019). In Grenoble, fine particle pollution was actually considered responsible for 145 deaths per year (i.e. 5.6% of deaths, with a margin of error of plus or minus 2%) (Inserm, 2019).

This situation encouraged the local authorities of Grenoble to be one of the first French metropolises to engage in the implementation of LEZ and take part in other ambitious projects to ameliorate air quality. Figure 1.1 presents the evolution of these LEZs.

Since January 2017, a LEZ has been set to the extended city center of Grenoble for freight transport vehicles (light commercial vehicles and heavy goods vehicles). Only the unclassified (the most polluting) goods transport vehicles were banned from driving in the LEZ between 6am and 7pm, from Monday to Friday. Starting in May 2019, this restriction was enlarged to 10 volunteer municipalities with a 24/7 ban, then, extended to 27 municipalities in 2020. Unlike other French LEZs, private vehicles are not yet concerned by these restrictions. However, the Metropolis of Grenoble, called La Metro, is considering the gradual introduction of restrictions for private vehicles[8]. The present chapter is part of the evaluation studies conducted by La Metro before the implementation of LEZs. Some of the results were communicated to La Metro as we joined the scientific committee[9] aiming to assist local decision makers.

Circulation restrictions are introduced following a standardised classification of the vehicles in six categories using Crit'Air stickers "Certificats Qualité de l'Air" (See the classification in appendix A.1). Since 2017, having the Crit'Air sticker on

[7] https://www.insee.fr/fr/statistiques/1285839

[8] The current study was actually partially funded by La Metro to make acceptability evaluations implementing LEZ for all vehicles.

[9] Sandrine Mathy, Hélène Bouscasse and myself.

the vehicle has become mandatory to circulate in the 49 municipalities of Grenoble. They are also used to restrict the most polluting vehicles from circulating during pollution peaks.

1.1.2 Related literature

Evaluating the population acceptability for the implementation of a public intervention such as LEZs and understanding its determinants are essential. It allows for public authorities to be more aware of the population expectations and adapt the planned accompanying policies in regards to their needs.

Considering acceptability as an influential factor of the success of such interventions has been confirmed in previous transportation studies assessing congestion and pricing policies (eg. Gu et al., 2018; Jagers et al., 2017; Rye and Ison, 2005). Some even encourage reaching out to the public through referendums to ensure more acceptability and legitimacy (Transport & Environment, 2018).

However, in the evaluation of LEZs, it is only recently that researchers have begun to address the issue of the acceptability and its determinants. We identify in the literature two streams of works depending on the moment of the LEZ evaluation in the implementation timeline of the measure.

The first stream includes ex-post analyses which are elaborated after the implementation of the LEZs. The existing literature focuses primarily on evaluating its environmental and health consequences (Ku et al., 2020; Moreno, 2020; Host et al., 2020). Even though these aspects are important and could influence the population acceptability, specific analyses of acceptability of LEZs and its determinants are still lacking.

An example from this small literature is the work of Oltra et al. (2021) who used survey data to evaluate the LEZs acceptability of residents of Barcelona after four months from partially implementing this measure. Their sample showed a general high acceptability with 64% of the participants declaring it being "acceptable" or "totally acceptable". Conducting a path analysis to assess the effect of attitudinal and socio-demographic factors on this acceptability demonstrated significant relation of individual characteristics with acceptability, in particular, perceived process legitimacy, affect, perceived global impacts and institutional trust.

The ex-post study of Tarriño-Ortiz et al. (2021) of LEZs in madrid, called "Madrid Central", also indicates an overall acceptability of the measure with 68% of the sample expressing "positive" or "very positive" thoughts about it. Using an ordered logit regression allowed identifying the limited role that socio-demographic characteristics play in explaining this public acceptability. However, Tarriño-Ortiz et al. (2021) noticed that younger-working participants with low income and living in shared-households expressed higher acceptability than the other groups of partic-

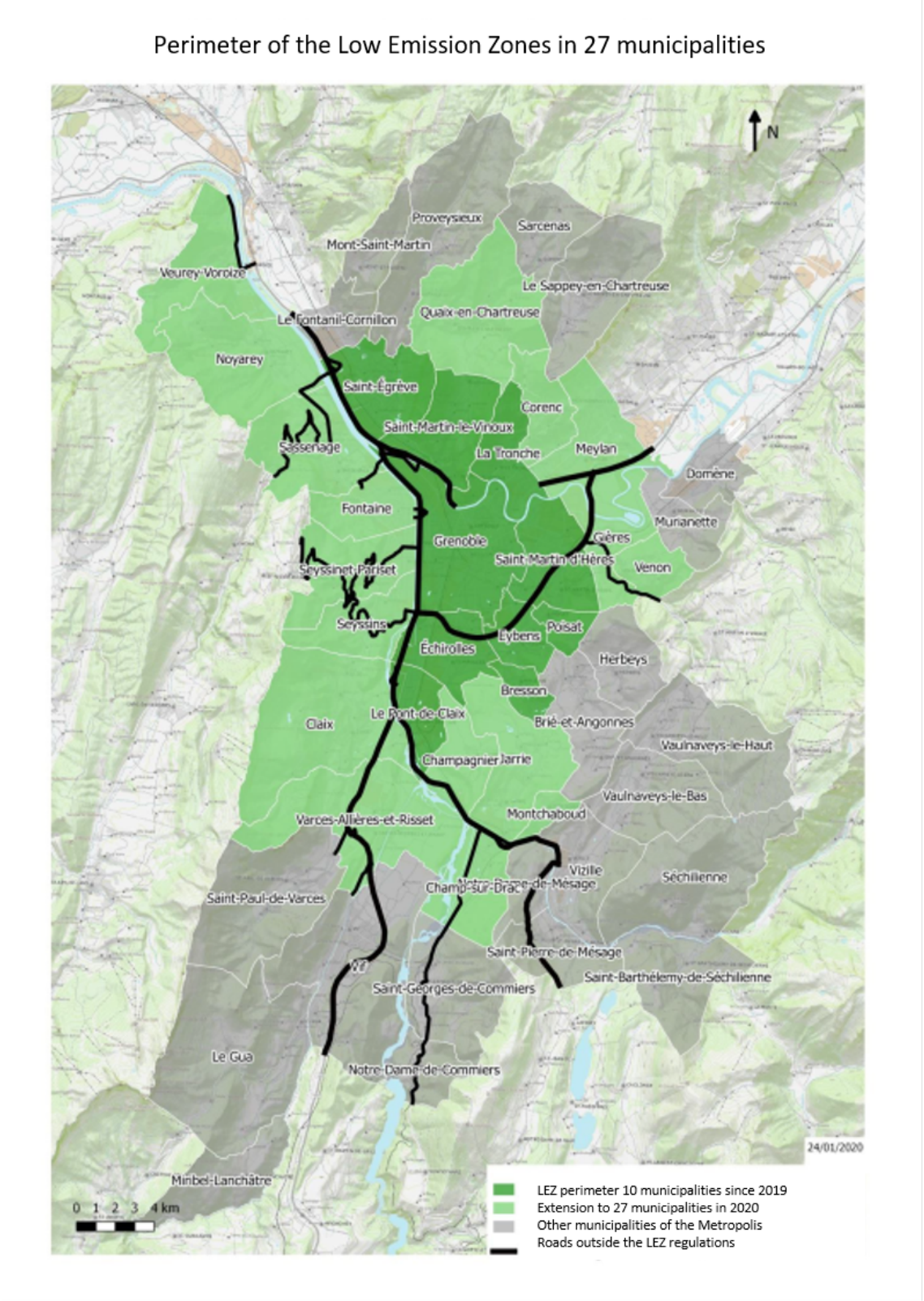

Figure 1.1: Map of the Low Emission Zone (LEZ) in Grenoble Metropolis (Source: Translated to English from www.Grenoble.fr)

ipants. The authors explained these results by the fact that this particular group is composed of less car-dependent individuals using mostly public transport, thus, less affected by the LEZ restrictions. People's mobility characteristics actually seem to influence their level of acceptability. For example, usual users of public transport or motorcyclists show higher acceptability of "Madrid Central". The results of this study also highlighted the important role of the individual's political ideology and environmental awareness on acceptability. In fact, politically left-wing participants showed a much higher acceptability than other political ideologies, especially supporters of right-wing parties. Also, more environmentally concerned individuals expressed more acceptability to the LEZ.

The second stream includes ex-ante analyses which are elaborated prior to the actual implementation of the LEZs. These analyses are usually based on hypothesised scenarios and allow for the public authorities to have an understanding of the feasibility of the measure and its expected consequences on different levels (eg. health, air pollution, mobility practices, acceptability).

In the case of French LEZs, the existing evaluations of this measure implemented ex-ante analyses to evaluate its environmental and health impacts, mostly in the Paris Metropolis case (i.e "Greater Paris"). These analyses are based on hypothetical scenarios of LEZs in Paris. The results confirm the positive impact of this public measure on reducing population exposure and the number of premature deaths (Host et al., 2020). However, some concerns have been expressed on the accessibility of these health co-benefits which could generate injustice between shares of the population (Moreno, 2020). For instance, the evaluation of Poulhès and Proulhac (2021) demonstrated that residents outside of the zone benefit from the LEZ but the most vulnerable population categories are the least advantaged by this measure. Such injustices could justify less acceptability from these populations. The identification of such negative social impact could even lead to the prematurely abandon of the public measure.

This was the case for the first French attempt of implementing a LEZ in 2010 in Grenoble Metropolis called Priority Action Zone for Air ("Zone d'actions prioritaires pour l'air", ZAPA). Even though the declared acceptability of the population supported the implementation of such a measure (according to La Branche and Charles (2012), 60% where favourable to the project ZAPA), the Metro dropped the project justifying this decision with identified risks of environmental and social injustices. Indeed, Charleux (2014) confirmed that the proposed LEZ in Grenoble would have created injustices between different social groups.

Both types of analyses ex-ante and ex-post give interesting results but different insights. The implementation of a LEZ presents different challenges before and after its implementation. For instance, the introduction of Madrid Central raised

controversy discussions in the political debates at both moments with a focus on its effectiveness to ameliorate air quality, its impact on individual mobility practices and retail services (Tarriño-Ortiz et al., 2021). Thus, making both analyses for the same LEZ measure is important to have a complete vision of the effectiveness and implication of such a measure. Since we are interested in studying the acceptability in the case of the future implementation of LEZs for private vehicles in Grenoble, an ex-ante acceptability evaluation is suitable.

Up until now, Grenoble limits its application of LEZs to utility vehicles, not including restrictions on private vehicles. Despite the relative improvement of the general air quality indicators of the Isère region according to Auvergne-Rhône-Alpes (2018), since 2000, 40% and 48% reduction for $PM_{2.5}$ and NO_x and the number of pollution episodes in Auvergne-Rhône-Alpes region (from 93 days in 2011 to 25 days in 2021)[10], the metropolis is still characterised with poor air quality. Thus, in an attempt to ameliorate air quality and its health consequence, La Metro is considering to further extend its LEZs and include restrictions on private vehicles.

The media focus on health issues related to air pollution and the increasing number of social movements and protests for better environment (eg. "Marche pour le climat") could have modified the perceptions and attitudes of the residents of this region about the air quality issues related to road traffic. This in turn, could have had influence on their opinions and acceptability of the LEZ project.

The present work is the first acceptability evaluation of LEZs in Grenoble contributing to the previously presented literature measuring the acceptability of the residents of Grenoble ex-ante introducing the LEZ and identifying the most influential determinants of this acceptability. The results are formulated as recommendations addressed to assist public authorities in the implementation of such a measure.

The remainder of the chapter is structured as follows. Section 2 presents the data collection and the used analysis methods, section 3 lays down the results that are then discussed in section 4 to formulate public recommendations.

1.2 Data and methods

1.2.1 Procedure and participants

Aiming to evaluate and explain the acceptability of the residents of Grenoble for local air quality improvement measures of LEZ, we use original data collected through a phone survey conducted between April and May 2019 within the QAMECS-SHS project[11]. The phone interviews were conducted by Alyce Sofreco survey insti-

[10] https://www.lyoncapitale.fr/actualite/en-2021-un-nombre-de-jours-de-vigilance-pollution-historiquement-bas-en-auvergne-rhone-alpes

[11] Qualité de l'air dans l'agglomération grenobloise: Evaluation de l'environnement, du comportement et de la santé. The project was funded by Ademe (Agence de la transition écologique)

tute. A total of 1,304 participants completed the questionnaire, among which 300 are residents of adjacent areas of Grenoble Metropolis which are Grésivaudan and Voironnais (see the map of the surveyed areas in figure A.2). We recruited this sample following pre-calculated quotas[12]. The phone interview lasted approximately 30 minutes per participant. Table 1.1 summarises the sample characteristics[13]. Nearly half of the sample was male (48%) and 49% are aged between 25 and 54 years old. We divide the 49 municipalities of the metropolis into three zones, A to C, with a fourth additional zone D. Accordingly, zone A consists of Grenoble city, zone B is the "urban center" of the urban area (cœur urbain), zone C includes peri-urban and rural or mountain territories and zone D is composed of Grésivaudan and Voironnais. The participants are almost equally distributed between the different levels of income but highly educated individuals are over-represented (54%).

Table 1.1: Sample characteristics

Observations = 1,304		**Proportion (%)***
Gender	Male	48.34
	Female	51.66
Age	18 to 24	13.02
	25 to 54	48.58
	55 or older	38.4
Zone of residence	A	25.27
	B	33.09
	C	11.76
	D	29.88
Income (€)	1000 or less	6.99
	1001 - 1500	9.36
	1501 - 2000	14.39
	2001 - 3000	18.83
	3001 - 4000	15.19
	4001 or more	21.11
	Do not want to answer	12.19
	Do not know	1.93
Education	University	54.45
	Non-university	45.55
Profession	Farmer, Craftsman or Shopkeeper	3.71
	Manager and higher intellectual profession	31.62
	Intermediate profession	27.87
	Employee	21.64
	Worker	9.54
	Unemployed and other inactivity	5.62

*Proportions are based on calibrated data.

and La Metro (Grenoble-Alpes Métropole)

[12]The quotas were calculated using data on the studied municipalities from the French population census of 2015 for the variables zone, age, gender and occupation.

[13]We calibrated the data using the Logit method with an upper bound = 1.9 and a lower bound =0.1 (See appendix A.3 for more details).

1.2.2 Questionnaire

We explain to the participants that La Metro is considering setting up a LEZ project. Thus, pre-2006 diesel vehicles and pre-1997 gasoline vehicles would be banned from entering the city center by 2022 (i.e. vehicles with a Crit'Air 4 and 5 sticker). We also present the project of total ban of diesel vehicles by 2024 similarly to the measure implemented in Paris.

Based on the literature review, we design the phone survey testing the effect of a group of determinants on the acceptability of these restrictions. The survey is organised in three main categories of determinants: socio-demographic characteristics, travel related characteristics and attitude and perception characteristics. Table 1.2 presents the items used to measure the variables included in each category.

First, the socio-demographic questions are about gender, age, zone of residence, income level, education level and profession. For comparability purposes and to make the reading of the results easier we create categories for some of these variables. For instance, using the year of birth in the age variable, we create three categories of different age levels.

Second, for the travel related questions the participants state if they own a vehicle and in case they do, we ask about the category of Crit'air sticker of their vehicle(s).[14] Also, asking about their occupation allowed us to identify their level of mobility. We actually suppose that an individual is "mobile" if he/she has a professional activity or he/she is, a pupil, a student or an unpaid trainee. We assume that such categories of people will probably make a high number of trips to go to work or to study and may be more dependent on the car. In parallel, we suppose that an individual is "less mobile" if he is unemployed, retired or pre-retired, a housewife/husband or in any other inactive situation. Then, we asked about their active mobility habits (i.e regularly using public transport, bicycle, walking or car sharing) assessing the level of automaticity in deciding to use an alternative mode to the car.

Third, we include 5-points Likert scale questions to assess the individual attitudes and perceptions that could influence the acceptability. These measures concerned the alternative modes to the car, the air quality issue in Grenoble and the benefits related to implementing a LEZ.

[14] If the participant did not know his sticker, we asked two additional questions about the type of energy and year of circulation of identify the sticker level.

Table 1.2: Items measuring the studied variables

Variable	Survey question	Response categories
Socio-demographic characteristics		
Gender	You are…	Male/Female
Age	What is your year of birth?	
Zone of residence	What is the name of the municipality where your main residence is located?	
Income	Can you tell us in which range your net monthly household income falls?	Less than 1000 euro to more than 4000 euro
Education	What is the highest level you have reached in your studies?	Multi-answer question
Profession	What is or was your main profession?	Multi-answer question
Travel characteristics		
Car ownership	How many cars do you have in your household?	
Crit'air sticker	Can you tell us which Crit'Air sticker is associated to your first vehicle?	Electric and hydrogen to Hors Ctit'air
Level of mobility	What is your current main occupation?	Multi-answer question
Active mobility habit	Deciding to use an alternative mode of transportation to the car is something that:	1.strongly disagree to 5.strongly agree
	You do automatically	
	You do without thinking about it	
	You do without having to consciously remember	
	You start doing before you know it	
Attitudes and perceptions		
Attitude toward the car	The car is more convenient than public transport	1.strongly disagree to 5.strongly agree
Attitude toward the bicycle	Bicycles are more convenient and less expensive than cars	1.strongly disagree to 5.strongly agree
Problem perception	Would you say that you are bothered on a daily basis by air pollution in the Grenoble area?	1.not bothered at all to 5.bothered
Environmental preoccupation	How interested are you in the issue of air quality in the Grenoble area?	1.not interested at all to 5.very interested
Preceived social faireness	Assuming the LEZ is implemented, people in precarious situations would be penalized	1.strongly disagree to 5.strongly agree
Preceived economic faireness	Assuming the LEZ is implemented, the local economy (shops, businesses) would be penalized	1.strongly disagree to 5.strongly agree
Perceived effectiveness on health	Assuming the LEZ is implemented, it will have beneficial effects on your health and that of your relatives	1.strongly disagree to 5.strongly agree
Perceived effectiveness on mobility	Assuming the LEZ is implemented, traffic in the area would be more fluid?	1.strongly disagree to 5.strongly agree
Perceived effectiveness on environment	Assuming the LEZ is implemented, air pollution would be reduced?	1.strongly disagree to 5.strongly agree
Acceptability		
Acceptability of LEZ	Rate the pollution control action of banning the most polluting cars from entering the city center	1.not at all acceptable to 5.totally acceptable

1.2.3 Analysis methods

Our data analyses relies on calibrated data. The details about the followed steps for calibrating the original data are presented in appendix A.3.

We start our analyses by doing some descriptive statistics of the variables of interest. These analyses are followed by a bivariate analysis. We use a number of statistical tests, depending on the type of the data, assessing the relations that may exist between the acceptability level (being a supporter or an opponent) of LEZ project and individual characteristics. We use non-parametric tests (Mann-Whitney test and Kruskal-Wallis test) for categorical and not normally distributed data and t-tests for comparing means of normally distributed data (Denis, 2020).

To have a more complete vision of the way the previously assessed individual characteristics interact and determine the acceptability of LEZ in Grenoble, we run a binary logit model. The variable modeled is the probability of being a supporter of this measure. Using a discrete choice model has been extensively used in existing transportation studies (Al-Salih and Esztergár-Kiss, 2021; Puan et al., 2019; Bouscasse, 2017) and has also been implemented in the assessment of acceptability of public interventions. For instance, Tarriño-Ortiz et al. (2021) used ordered logit modeling to assess the acceptability of LEZ in Madrid.

1.3 Results

1.3.1 Descriptive statistics

Figure 1.2 presents the distribution in our sample of the levels of acceptability for the project of LEZ in Grenoble. We notice a majority of 54.26% being supporters of the project, 28.35% are opponents and 17.38% are neutral or indecisive.

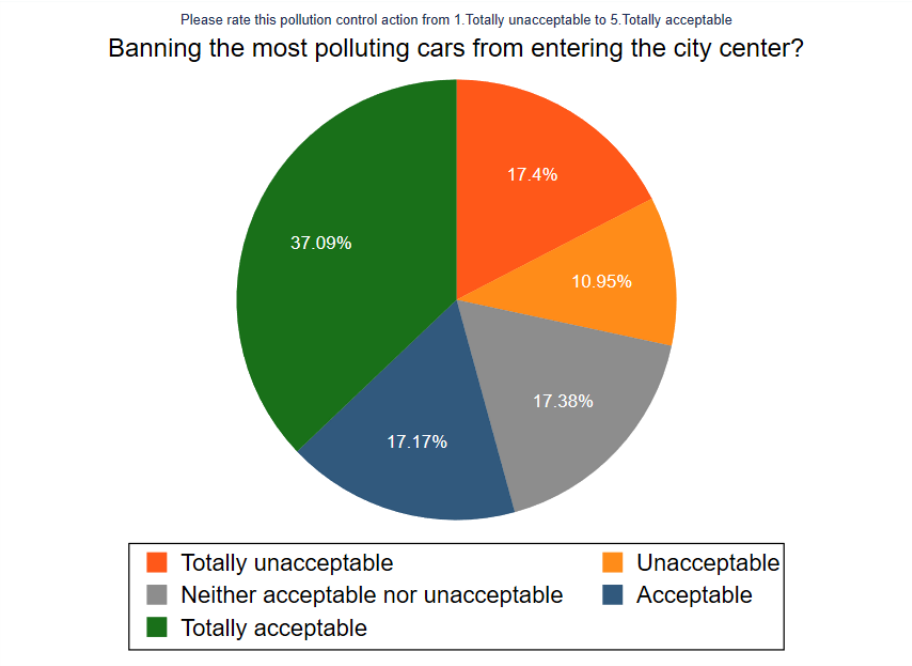

Figure 1.2: Individual acceptability level of LEZ in Grenoble

Following this categorisation of supporters versus opponents of the project, we assess the difference in socio-demographic characteristics of both sub-samples. Table 1.3 shows the limited role of these characteristics in influencing the levels of acceptability. This is the case even with relatively large difference in certain characteristics between both types of participants. For instance, among the supporters 31% are male whereas only 18% are in the opponents group. However, the gender of the participant does not have a significant effect on being part of one group or another. Another example is the level of education. We notice a much larger share of highly educated individuals in the supporters group with 37% share compared to 17.22% for opponents. Still, this variable has only a low significant (at 10% level) impact on acceptability. These results are in accordance with the previously identified minor role of these socio-demographic variables by Tarriño-Ortiz et al. (2021) for the acceptability of LEZ in Madrid.

The travel related personal characteristics has a more significant effect on the acceptability of LEZ. In table 1.4, a larger share of supporters owning less polluting vehicles following the Crit'air stickers or do not own a vehicle at all. Comparing the

participants answers we find that owning a car, especially a polluting one, leads to lower acceptability. In particular, using post hoc test (Dunn test), we find that those with "Hors Crit'air" stickers express lower acceptability of LEZ than those with the least polluting vehicles who own "Electric and hydrogen" stickers (p-value= 0.0004 $<$ 5% significance level) and those who do not own a car (p-value =0.0087 $<$ 5% significance level). We also find that those who own a car with "Crit'air 3" sticker have lower acceptability of LEZ than those who do not own a car (p-value = 0.0162 $<$ 5% significance level). These results are in line with the general observation of previous studies of acceptability of LEZ (eg. Tarriño-Ortiz et al., 2021; Oltra et al., 2021) which conclude that people with polluting vehicles express lower acceptability than those with less polluting vehicles or who do not own a car. They are less concerned about the restrictions and their impact on their daily lives.

The mobility habits also play a significant role on the acceptability of LEZ. We find that supporters of this measure have stronger active mobility habits when compared to the opponents (p-value = 0.000 $<$ 5% significance level). This is related to the fact that those with active mobility habits depend less on the private vehicle in their traveling so they are less impacted by the restrictions of LEZ.

The personal attitudes and perceptions seem to have the most important impact on the acceptability of LEZ. Following the results summarised in table 1.5, supporters have significantly more positive attitudes to public transport and bicycle as alternatives to the car compared to the attitudes expressed by the opponents (4.08 $>$ 3.58, p-value = 0.000). Supporters are generally significantly more concerned about the air quality in their region (3.9 $>$ 3.44, p-value = 0.000), and they perceive the air pollution in Grenoble more as an important issue (2.73 $>$ 2.53, p-value = 0.021), compared to the opponents. Results emphasise the crucial role of perceived fairness in the acceptability of this measure. Whether social or economic, perceiving LEZ as not fair is more present with opponents. This result goes along the results of Charleux (2014) about the feelings of injustice that a LEZ could generate which seem to be not only environmental but also social and economic. Lastly, we find that perceived effectiveness of LEZ is significantly different between supporters and opponents for three assessed levels: health, mobility and environment. Supporters think more than opponents that LEZ will have beneficial effects on one's health and the health of his family (3.86 $>$ 2.76, p-value = 0.000). They also have higher perceptions (3.74 $>$ 2.69, p-value = 0.000) of the impact of LEZ on mobility, in particular, in reducing congestion and making traffic in the zone more fluid. Supporters of LEZ also believe more than the opponents in the potential of this measure to reduce air pollution in the zone (3.86 $>$ 2.83, p-value = 0.000).

Table 1.3: Socio-demographic characteristics and their influence on acceptability

Proportion (%)		**Supporters (n= 710)**	**Opponents (n= 364)**	**p-value**
Gender	Male	30.98	17.96	0.129
Age	18 to 24	8.78	4.09	0.101
	25 o 54	30.37	18.37	
	55 or older	26.52	11.86	
Zone of residence	A	16.89	8.08	0.336
	B	22.32	11.13	
	C	6.86	4.87	
	D	19.61	10.24	
Income	1000 or less	4.91	2.41	0.068
	1001 - 1500	5.53	3.6	
	1501 - 2000	8.41	6.04	
	2001 - 3000	13.03	5.88	
	3001 - 4000	10.44	5.17	
	4001 or more	15.07	5.57	
	Do not want to answer	7.28	4.68	
	Do not know	1.02	0.99	
Education	University	36.88	17.22	0.080
Profession	Farmer, Craftsman or Shopkeeper	2.76	1.25	0.830
	Manager and higher intellectual profession	20.27	10.96	
	Intermediate profession	18.64	9.29	
	Employee	13.79	8.001	
	Worker	5.50	3.8	
	Unemployed and other inactivity	3.93	1.8	

Note: Proportions and non-parametric tests are based on calibrated data.

Table 1.4: Travel related characteristics and their influence on acceptability

		Supporters (n= 710)	**Opponents (n= 364)**	**p-value**
Crit'Air stickers / car ownership (%)	Electric and hydrogen	3.13	0.82	0.0004
	Crit'Air 1	17.81	7.96	
	Crit'Air 2	15.98	8.72	
	Crit'Air 3	11.05	7.94	
	Crit'Air 4	2.51	2.32	
	Crit'Air 5	0.86	0.24	
	Hors Crit'Air	3.18	2.76	
	No car	9.63	3.1	
	Do not know	1.53	0.47	
Level of mobility (%)	Mobile	38.26	20.75	0.517
Soft mobility habit (mean)	Choice of alternative is automatic	3.55	3.2	0.000

Note: Proportions and tests are based on calibrated data.

Table 1.5: Personal attitudes and perceptions and their influence on acceptability

Mean		**Supporters (n= 710)**	**Opponents (n= 364)**	**p-value**
Attitude toward the car	Practicality compared to public transport	3.76	4.09	0.000
Attitude toward the bicycle	Practicality compared to car	4.08	3.58	0.000
Problem perception	Air pollution in Grenoble	2.73	2.53	0.021
Environmental preoccupation	Air quality in Grenoble	3.9	3.44	0.000
Prceived social faireness	Penelizes precarious people	3.56	3.96	0.000
Prceived economic faireness	Penelizes local economy	3.01	3.49	0.000
Perceived effectiveness	On health	3.86	2.76	0.000
Perceived effectiveness	On mobility	3.74	2.69	0.000
Perceived effectiveness	On environment	3.86	2.83	0.000

Note: means and tests are based on calibrated data.

1.3.2 Determinants of LEZ acceptability in Grenoble

The results presented in table 1.6 of the binary logit regression confirm the previously identified low impact of socio-demographic variables on the probability of being a supporter of this measure. Actually, none of the included socio-demographic variables has a significant effect on this probability.

Results show that the individual travel characteristics play a less important role than previously identified with the bivariate analysis. We actually find that only Crit'air sticker significantly determines acceptability. Having "Crit'air 4" (Odds Ratio OR = 0.21, p-value = 0.020) or "Hors Crit'air" (OR = 0.18, p-value = 0.013) stickers significantly increases the probability of being an opponent compared to having an "Electric and hydrogen" sticker. Unexpectedly, having a "Crit'air 5" vehicle does not influence significantly the acceptability. This could be due to the small number of participants declaring having this specific Crit'Air (only 16 participants out of the sample).

The most important variables determining acceptability are attitudes and perceptions. Participants who are more concerned about the environment are more likely to support an air quality improvement measure such as a LEZ (OR = 1.27, p-value = 0.022). However, contrary to the existing literature characterising the LEZ as a possible source of environmental and social unfairness, in our sample participants' acceptability is only influenced by economic but not social injustice (OR = 0.85, p-value = 0.037). In particular, those perceiving it as economically unfair are less likely to be supporters of this measure. Lastly, the model demonstrates a significant effect of the three types of perceived effectiveness on acceptability with the one on mobility having the strongest effect on the odds of being a supporter (OR = 1.37, p-value = 0.000). The perceived effectiveness on health had an OR equal to 1.32 (p-value = 0.002) and the one related to perceived effectiveness on environment was the lowest, but always significant, with an OR equal to 1.27 (p-value = 0.013).

Table 1.6: Acceptability of LEZ in Grenoble - Binary logit regression

Supporter	**OR**	**SE**	**p-value**
Socio-demographic characteristics			
Female	1.38	0.29	0.125
Age			
25 -54 ans	0.55	0.25	0.191
+55 ans	0.58	0.28	0.257
Zone of residence			
B	0.85	0.19	0.454
C	0.87	0.32	0.696
D	0.89	0.28	0.726
Income			
1001 - 1500	0.62	0.34	0.390
1501 - 2000	0.47	0.23	0.131
2001 - 3000	1.16	0.61	0.782
3001 - 4000	0.862	0.44	0.775
4001 or more	1.26	0.65	0.661
Do not want to answer	0.79	0.43	0.670
Do not know	0.31	0.29	0.222
University	0.96	0.22	0.845
Profession			
Manager/higher intellectual prof.	0.84	0.44	0.746
Intermediate profession	1.19	0.62	0.729
Employee	1.22	0.64	0.707
Worker	1.82	1.11	0.329
Unemployed and other inactivity	1.02	0.71	0.982
Travel characteristics			
Crit'air sticker			
Crit'Air 1	0.79	0.44	0.666
Crit'Air 2	0.45	0.26	0.163
Crit'Air 3	0.50	0.29	0.234
Crit'Air 4	0.21	0.14	0.020
Crit'Air 5	1.08	1.2	0.944
Hors Crit'Air	0.18	0.12	0.013
No car	0.58	0.36	0.386
Do not know	0.43	0.38	0.343
Less mobile	0.98	0.25	0.923
Soft mobility habit	0.99	0.09	0.883
Attitudes and perceptions			
Attitude toward the car	0.85	0.07	0.052
Attitude toward the bicycle	1.13	0.09	0.105
Problem perception	0.84	0.07	0.051
Environmental preoccupation	1.27	0.13	0.022
Perceived social fairness	0.86	0.07	0.062
Perceived economic fairness	0.85	0.06	0.037
Perceived effectiveness on health	1.32	0.12	0.002
Perceived effectiveness on mobility	1.37	0.11	0.000
Perceived effectiveness on environment	1.27	0.12	0.013
Constant	1.01	1.13	0.993
Observations = 743			
F-adjusted test statistic = 0.938			
p-value = 0.491			

Note: OR = Odds Ratio, SE = Standard Error

1.3.3 Adaptation to the LEZ and accompanying measures

We complete our analyses of the acceptability of the LEZ in Grenoble by looking first at the adaptation behaviours stated by the participants who would be affected by a LEZ banning Crit'Air 4 or 5 vehicles. Second, we ask the whole sample for their opinion about their preferences in terms of accompanying public measures. In this regards, we present 12 suggestions listed in figure 1.4. The questions asked in the survey are presented in appendix A.4.

Complementing the acceptability evaluations with such analyses has rarely been done and constitute an additional originality of the present work. To the best of our knowledge, the only previous study making similar analyses is the one by Tarriño-Ortiz et al. (2021) evaluating Madrid Central. They included in their survey an open question where the respondents could suggest actions that would enhance the acceptability of the LEZ in Madrid. The three most frequently indicated measures where the increase of the frequency of the public transport in the zone, giving subsidies to renew the car fleet and promote car sharing.

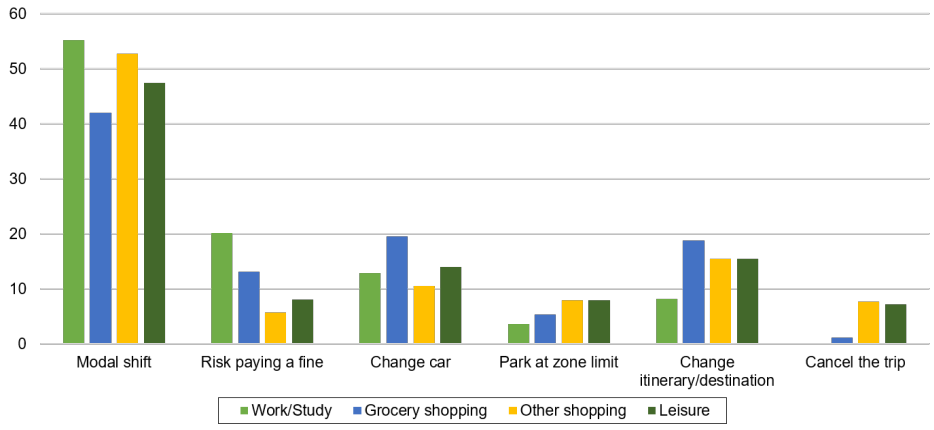

Figure 1.3: Stated behavioural change in case of implementing a LEZ

First, regarding the behavioural change resulting from a LEZ, figure 1.3 summarises the participants' statements for different categories of travel (work/study, grocery shopping, other shopping and leisure). For all the travel categories, the majority of people affected by this measure are prepared to change their mode of transport to alternatives to the car (bus, tram, bicycle, walking and car sharing). This is true especially for work/study trips where a share of 55% declare this option. For the other categories of travel, modal shifting is declared by 42 to 53% of the sample. Also, depending on the purpose of the trip, there are 5.6 to 20% of the participants willing to face a risk of paying a fine by entering the zone with the banned sticker. The highest share of 20% refers to a work/study trip which drops to 13% for grocery shopping. We believe that these shares are underestimated due to social desirability bias meaning that some respondents do not dare to give such

an answer by fear of being judged by the interviewer, in particular since it is a phone survey. Besides, depending on the travel category, there are shares of 10.5 to 19.5% of participants willing to change the car to get a less polluting one. Some participants said they would change the itinerary or the destination, especially for shopping (18.5% for grocery and 15.5% for other) and leisure (15.4%). The least adaptive behaviour that was chosen is cancelling the trip[15], especially in the case of a grocery shopping trip with only 1% share versus around 7% share for either shopping or leisure trips.

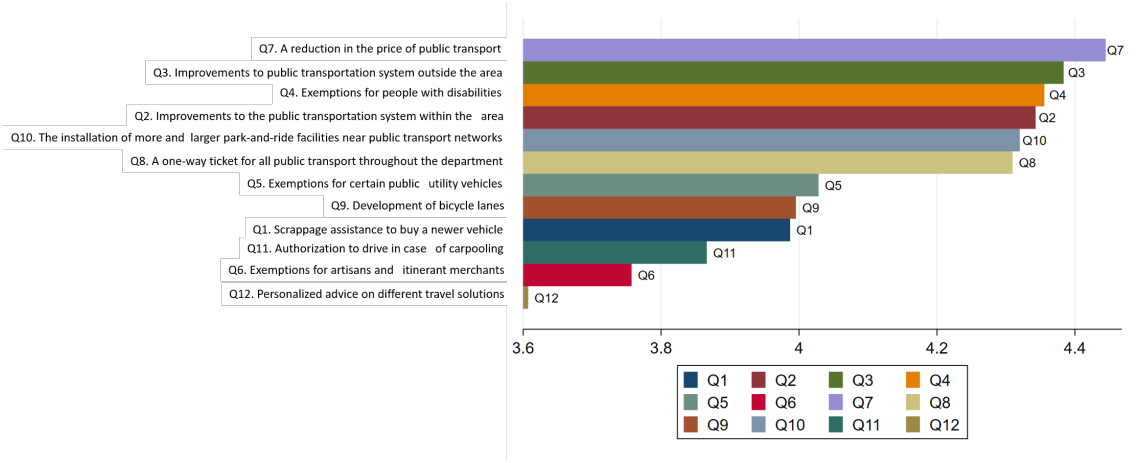

Figure 1.4: Mean perceived utility of accompanying measures of the LEZ project

Table 1.7: Perceived utility of accompanying measures in function of the LEZ acceptability

Accompanying measure	**Supporters (n= 710)**	**Opponents (n= 364)**	**p-value**
Q1. Scrappage assistance to buy a newer vehicle	4.14	3.7	0.000
Q2. Improvements to the public transportation (PT) system within the area	4.54	4.04	0.000
Q3. Improvements to PT system outside the area	4.49	4.19	0.000
Q4. Exemptions for people with disabilities	4.48	4.12	0.000
Q5. Exemptions for certain public utility vehicles	4.15	3.83	0.001
Q6. Exemptions for artisans and itinerant merchants	3.84	3.6	0.009
Q7. A reduction in the price of PT	4.51	4.29	0.004
Q8. A one-way ticket for all PT throughout the department	4.39	4.12	0.002
Q9. Development of bicycle lanes	4.26	3.57	0.000
Q10. The installation of more and larger P&R near PT networks	4.48	4.06	0.000
Q11. Authorization to drive in case of carpooling	4	3.56	0.000
Q12. Personalized advice on different travel solutions	3.85	3.21	0.000

Second, concerning public accompanying measures to the implementation of LEZ in Grenoble, we present 12 possibilities previously used in similar public interventions. We assess the perceived utility of these measures using 5-points Likert scales ranging from 1.not at all useful to 5.useful. We notice a general appreciation of all the measures with mean scores ranging between 3.6 points to 4.4 points for the whole sample (See figure 1.4). There is a strong demand for measures to address the economic, physical and social accessibility of public transport. According to the

[15]This option was not included for work/study trips.

participants answers, the least useful measure is communicating information about the existing mobility solutions (Q12). Comparing the level of perceived utility of these measures between the opponents and supporters, we notice a significant difference with the supporters having higher levels (see table 1.7). This means that acceptability of the LEZ is also related to the acceptability of its accompanying measures. This is an interesting result for public authorities since it further underlines the importance of considering acceptability in the design of their measures.

1.4 Discussion and policy recommendations

Existing literature evaluating the implementation of air quality improvement measures mostly assesses their environmental and health consequences. However, less is known about their social consequences, in particular about the public acceptability as an essential determinant to efficiently achieve their objectives. We contribute to this scarce literature by evaluating the acceptability of LEZ project in Grenoble, France. This is the first work focusing on this specific case and assessing the acceptability of a LEZ prior to its actual implementation. We used survey data studying the effects of socio-demographic characteristics (eg. age, gender), travel related characteristics (eg. car ownership and pollution characteristics, mobility habits) and attitudinal and perception characteristics on the individual acceptability of LEZ.

Our sample demonstrated a relatively high acceptability of this measure with 54.26% of participants thinking that it is acceptable or very acceptable. This result is comparable to previous acceptability levels in other European cities. It is also similar to the specific evaluation of the acceptability of ZAPA in Grenoble La Branche and Charles (2012) in which 59% of the sample (after being well-informed about the measure and its consequences) were in favour of this measure.

Our findings show that acceptability of LEZ, at least for the Grenoble case, is weakly related to socio-demographic characteristics. This result is similar to what Tarriño-Ortiz et al. (2021) identified in their evaluation of LEZ acceptability in Madrid.

However, travel related characteristics seem to play a more important role in defining this acceptability. We are the first to consider the type of "Crit'air" sticker in this type of evaluation. We actually see that those having a polluting "Crit'air" sticker are less in favour of this measure. This is logical since they are the most directly affected in their mobility practices by this measure. It would be interesting for future studies on acceptability evaluation to include this variable in order to make comparisons.

Attitudes and perceptions emerge as the most important determinants of public acceptability. The more people are concerned, the more they are aware of the

air quality problem and the more they believe in the effectiveness of the LEZ, the stronger their acceptability. These results highlight the importance of good communication from authorities to the public about the objectives of the proposed air quality improvement measures and their expected consequences. This would help the public to build well-established and more objective judgements of their acceptability to the measure.

Even though perceived fairness (eg. freedom or environmental impact) was previously identified as a potential blocking factor for accepting a measure of air quality improvement (Jagers et al., 2017), and more particularly LEZ (Oltra et al., 2021), our participants seem to be more concerned about the economic fairness than the social fairness. In this regards, further investigations on the affected populations should be done to identify the specific barriers affecting their acceptability and propose adequate accompanying measures.

These results present interesting insights for the local authorities of Grenoble since our sample is representative of the population of the Metropolis. However, generalising these results to other French or European cities need to be done with caution given that the residents of Grenoble are particularly sensitive to the air quality issue expressed through the high environmental preoccupations. Similar analyses than the ones done in the present work should be applied in different settings to make comparisons.

Given the very important impact of attitude and perception variables on acceptability, it would be interesting for public authorities to exploit insights from behavioural studies in order to guarantee more acceptability from the targeted population. For this purpose, we recommend creating bridges between different disciplines (eg. economics, psychology, sociology) and sectors (eg. transport, environment, health) to have coherent objectives and strategies. For instance, noticing the significant influence of individual perceptions on acceptability, this type of variable deserves further investigation using tools from psychology to create interventions that influence them with economic tools such as nudges. The consequences of this acceptability could be identified on three sectors: an impact on the transport sector through mobility change, the environmental sector through reduced air pollution and the health sector through reduced pollution exposure and more physical activity. Thus, we encourage communication between the different scientific and political parties to have consistency between all levels of government.

Going beyond the evaluation of the acceptability of the LEZ in Grenoble, we proposed to the participants to state their adopted behaviour in case this measure was implemented and to evaluate a number of accompanying measures. The results demonstrate that the most affected individuals have a general preference for modal shifting to active modes, especially public transport and bicycle. We also find that all

the participants (affected or not) encourage the improvement of the public transport as a service in terms of price reduction, the amelioration of the transport network inside and outside of the zone and propose financial aids for people with disabilities.

Our evaluation of the acceptability gives a first description of the attitudes of the residents of Grenoble in regards to LEZ and some interesting insights for public authorities to harness. The acceptability is the result of a combination of variables that we partially investigate through the present work. However, there are still some variables that we did not include in our evaluation and that could be considered in future acceptability studies. For example, we did not ask for political ideology in regards to the sensitivity of such information. This variable had a very important impact on acceptability of LEZ in previous studies such as the one by Tarriño-Ortiz et al. (2021), thus, it should be included in future research if possible.

Chapter 2

What is the role of active mobility habits in the relationship of selfdetermined and non-selfdetermined motivations with modal shift intentions? A mediation analysis

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Abstract

There is little research on the role of motivations in determining intentions to engage in pro-social or pro-environmental behaviours. In this chapter we rely on the Self-determination theory (SDT) to assess the relationship between individual motivations (selfdetermined SDM and non selfdetermined NSDM) and intentions to modal shift. We additionally evaluate the mediating role of active mobility habits in this relationship. To do this we build and test theoretical models using structural equation modeling. The results show that if habits concerning the use of alternative modes to the car are not taken into account, the SDM has a significant impact on intention, but not NSDM. However, the introduction of habits in the model shows that habits play the role of full mediator in the relationship between both motivations and intention. These results are useful for a better understanding of the psychological mechanisms of modal choice changes and the targeting of measures aimed at encouraging the use of active modes.

Keywords: self-determination theory, active mobility habit, intentions, mediation

2.1 Introduction

Understanding the individual determinants underlying the adoption of less polluting and more active modes of transport is essential to design efficient individual behavioural change interventions improving air quality (Viana et al., 2020; Host et al., 2020; Johansson et al., 2017) and the population health (Flint and Cummins, 2016; Celis-Morales et al., 2017; Jaocob et al., 2019). Researchers actually underline the important role that the citizen plays as an active actor of change to achieve these objectives. This active individual involvement calls for motivations that could either be intrinsic or extrinsic (Thiermann and Sheate, 2020). Thus, the individual is no longer a passive receiver of public interventions but an active part and determinant of its success.

The study of individual engagement in pro-social or pro-environmental behaviour has long been done using theories that are based on the underlying assumption that individual decision is driven by norms and values (Steg and Nordlund, 2018). The most prominent example of such a theory is the Theory of Planned Behaviour TPB (Ajzen, 1991). It is based on the assumption that individuals make reasoned decisions and that behaviour is the result of the intention to engage in it. The stronger the intention, the more effort the person will put into the behaviour and the more likely he is willing to commit to implementing this behaviour (Steg and Norlund, 2012). In the TPB, the intention depends on three variables : the attitude towards the behaviour (positive or negative perception of the behaviour), the subjective norm (perceived social pressure) and the perceived behavioural control (ease or difficulty in performing the behaviour). Motivations are thus not included as a fundamental determinant of individual behaviour in the original TPB.

Studies that have been interested in investigating the role of individual motivations more likely use the Self-Determination Theory (SDT) (Deci and Ryan, 1980; Deci et al., 1985). Despite its success in characterising the motivations behind the adoption of pro-environmental behaviour (Pelletier, 2002), we agree with Thiermann and Sheate (2020) on the fact that this theory "has not been on the radar of mainstream environmental psychologists" and even less environmental economists.

The SDT defines a continuum of motivations ranging from selfdetermined motivation (SDM) to non selfdetermined motivation (NSDM). These motivations are related to fulfilling basic psychological needs (Vansteenkiste et al., 2020) to foster well-being and health. The adoption of a behaviour that is motivated through SDM has meaning for the individual since it originates from internal factors of interest, enjoyment or satisfaction (eg. I take the bus because I enjoy watching the scenery). Whereas the adoption of a behaviour resulting from NSDM is not necessarily meaningful for the individual since it results from separate factors from the behaviour

itself such as a sense of social pressure or feelings of guilt or shame. In this case, doing the behaviour would not be a source of satisfaction or pleasure for the individual.

In this chapter, we mobilise the SDT to study the relation between individual motivations (i.e. SDM and NSDM) and intentions to modal shift to active mobility (public transport, bicycle and walking). The choice of an alternative mode to the car could be motivated by the well-being that the chosen mode generates. Indeed, a person could choose to make her trip in the public transport to enjoy the natural scenery or for the possibility that it offers for doing tasks (eg. reading, writing, sleeping) during the trip. Another person could choose walking or cycling for the health gains that they generate since they are valid means for practicing physical activity[4]. The literature about physical activity practice, and more generally psychological health studies, extensively implement SDT as a study framework for investigating motivations behind the adoption of healthier practices in everyday tasks (Niven and Markland, 2016; Hagger and Chatzisarantis, 2009; Moller et al., 2006). Considering transportation choice as a mean of practicing physical activity and trying to understand the motivations behind it further justifies our choice of the SDT as a theoretical study framework. Using this theory would bring a new perspective to the transportation study literature and further insights about the possible determinants of modal shifting and for public interventions. Additionally, this work creates a bridge between transportation studies and health psychology studies.

In the field of transport behaviour, the role of habits is very strong (Şimşekoğlu et al., 2015; Gardner, 2009). Indeed, even if the motivation to choose an alternative mode to the car is strong, habits that conflict with these motivations could prevent modal shift. Existing literature already confirms the significant influence of habits on behavioural intentions (Gardner, 2015). Based on the definition of habits as "behaviours that became automatic through repeated practice" (Radel et al., 2017), choosing everyday the mode of transport to go to work, to university or elsewhere is a repeated decision that could become a habit following an automatic decision process. Thus, if an individual has a habit of using the car automatically, deliberate consideration of different travel options may be limited (Eriksson et al., 2008). This would mean that using an alternative mode to the car is limited by the pre-existence of the habit of using the car in addition to the lack of habitual use of public transport or bicycle (that we could call active mobility habit). With the apparent important influence of habits on intentions, if these habits are disrupted it would open a window through which directly influencing the intentions and motivating the individuals to consider other options is possible. Here comes the contribution of the present work to

[4]https://www.euro.who.int/en/health-topics/environment-and-health/Transport-and-health/data-and-statistics/physical-activity2

a better understanding of the intention-motivation relation and the impact of active mobility habits on this relation. A good understanding of the relationships between these determinants would allow better targeting of public policies and measures to encourage the use of active modes as a socially desirable behaviour.

Despite the existence of a bundle of previous studies investigating the influence of habits on intentions, less is known about the role of habits in the motivation-intention relationship, specifically in the case of studying mobility practices. This work is an attempt to fill this gap by not only assessing the motivation-intention relationship, but also testing the mediating role of active mobility habits in this relationship.

The results of structural equation models (SEM), ran on original data collected through a phone survey, show that SDM (i.e. feeling of pleasure, belief in the usefulness and importance of modal shift) is positively correlated with higher active mobility habits and modal shift intentions. The effect of this type of motivation on intentions by considering habits is only indirect, confirming the strong influence of mobility habits on behaviour change. In contrast, NSDM (i.e. social pressure, fear of being criticized or judged) is negatively correlated with active mobility habits and does not significantly influence modal shift intentions.

The remaining of this chapter is organised as follows: section 2 presents the related literature. Section 3 displays the theoretical model and the tested hypotheses. Section 4 introduces the collected data and the methodology of analyses. Section 5 presents the results. Section 6 is a discussion with some conclusions.

2.2 Related literature

The SDT framework allows characterising the individual motivations considering the context and the environmental factors (Deci et al., 1985). Starting from the assumption that an individual is an active agent that has a goal-pursuit mindset (Ryan and Deci, 2000), he aims to engage in activities that allow full-filling mainly three innate psychological needs: 1) competence meaning that the person needs to believe in his skills and capability to succeed, 2) relatedness which concerns the need to feel connected to other people and have a sense of belonging and 3) autonomy which relates to the need to feel as the originator of the behaviour and having control over his personal actions. Meeting these needs is directly linked with better psychological health and overall well-being (Deci and Ryan, 2000).

In their description of motivations, Deci and Ryan (1980) use the SDT to make a distinction between selfdetermined and non- selfdetermined behaviours using an "autonomy-control continuum" of motivations (Thiermann and Sheate, 2020). Figure 2.1 illustrates this continuum. According to this continuum, individuals whom

motivation is selfdetermined generally succeed in fulfilling the three previously mentioned needs being responsible of their own actions, autonomous and feeling an alignment between their personal values and those resulting from the realisation of the action (De Groot and Steg, 2010; Hagger and Chatzisarantis, 2009). In the case of practicing physical activity through active mobility, an example of such motivation would be the feeling of pleasure when cycling or the believe of its positive consequences on one's health. On the contrary, when individuals' motivation is non selfdetermined, it is resulting from an external pressure that could be social or institutional. Thus, the individual feels controlled by these external forces which could take the form of feelings of guilt, shame or fear of disapproval (Thiermann and Sheate, 2020; Hagger and Chatzisarantis, 2009). For instance, if an individual works in an environment where his colleagues are usual cyclists who are always boasting about the benefits of this mode, coming everyday by car would make him feel a lack of belonging to this group and even ashamed of his mobility practices.

When the individual is not selfdeterminally motivated nor non selfdeterminally motivated, he is considered amotivated. Amotivation is defined as the absence of intention (Radel et al., 2017, p.2). Pelletier et al. (1999) explain this lack of motivation resulting in the fail to engage in pro-environmental behaviours by the individual's believes about the low capability of doing the behaviour or his believes about its low real impact on the environment (Deci and Ryan, 2000). In the case of using public transport, amotivation could be explained, for instance, by the unfamiliarity with the transport network or the pricing systems or ignorance of the positive impact of this behaviour on the environment and health. As for cycling, amotivation could be due to prior prejudices about the safety of this mode or excessive physical effort required to reach the destination.

Existing literature applying the SDT to study motivations confirm the positive relation between SDM and intentions to do the behaviour and the way such motivation allows for more sustainable engagement in the desired behaviour. However, NSDM has a lower impact on the intentions and the sustainable adoption of the behaviour. These results are particularly true for pro-environmental behaviours (eg. recycling, using an environmentally performing car) and healthier behaviours (eg. physical activity, healthier diet).

Considering motivation as a determinant of individual pro-environmental behaviour has been demonstrated by De Groot and Steg (2010) to have a significant relation with behavioural intentions to choose an environmentally friendly car and make donations to an environmental organisation. This is true especially for the SDM. However, individual values seem to be a more powerful predictor of pro-environmental preferences of intentions than motivations. This result does not deny the significant effect of motivations on values, which in turn influence intentions. A

more recent study of Thiermann and Sheate (2020) also confirms the significant effect of SDM on the probability to engage in a pro-environmental behaviour in order to reach long-term social well-being.

Using SEM with collected self-reported data on household energy-saving behaviours, Webb et al. (2013) also found that SDM directly predicts consumers' energy conservation intentions. This type of motivation even better predicts the studied behaviour than other more established determinants in the literature such as the past behaviour. However, NSDM do not seem to influence the intentions nor the behaviour.

Motivations play also a significant role on the engagement in healthier practices. The meta-analysis of 36 health studies (mainly about physical activity) done by Hagger and Chatzisarantis (2009), through which they generated averaged correlation coefficients testing an integrated model joining the TPB and the SDT, demonstrated that SDM predict intentions with a small but significant direct effect. This is an interesting result for us but motivations were measured as one latent construct confounding elements of both SDM and NSDM. We feel that it would be better to distinguish the two motivations, SDM from NSDM. This would give a more accurate view on the type of motivation that influences the studied relations.

It is clear that motivations are a significant determinant of human behaviour, in particularly, SDM. In this regard, Moller et al. (2006) state that SDM and choice, as opposed to NSDM and choice, "are positively associated with maintained behaviour change, effective performance, and psychological well-being".

Despite the identified significant effect of motivations on intentions, and considering that transportation practices have both environmental and health consequences, the existing transportation studies rarely consider SDT as a study framework. To the best of our knowledge, we at most find one study by Niven and Markland (2016) about walking behaviour but considering it only as a mean to engage in physical activity through different walking purposes among which is transportation. It is actually the purpose of the present work to contribute to this small literature trying to better understand the motivating process underpining the individual intentions to modal shift. However, since our aim is to explain intentions, we only consider individuals that have a minimum of motivation (SDM or NSDM). Thus, amotivated individuals were discarded using filters in our survey.

Using a health psychological theory such as the SDT in transportation studies to understand modal choice brings a new perspective to this discipline. We actually believe that understanding and modifying mobility choices has a multidimensional aspect influencing individual health and the environment. Thus, scientists from concerned fields (eg. transportation, urban planning, health and environment sciences) should work together and use their respective scientific approaches as complemen-

tary to have a better understanding of ways to efficiently influence mobility choices.

Despite their interesting results, such collaborations are emerging but remain scarce. For instance, a recent study of Koszowski et al. (2019) brought together insights from transport planning, urban planning and public health proposing policy measures supporting active mobility. Their review demonstrated the existence of common objectives between disciplines and sectors interested in active mobility. The review of Sallis et al. (2004) also encouraged collaborations between researchers identifying possible bridges to create between transportation (urban design and transport) and health (physical activity) studies. This type of collaborations allows formulating consistent recommendations for public authorities to implement their interventions' design. The present work is an additional contribution to these interdisciplinary transportation studies.

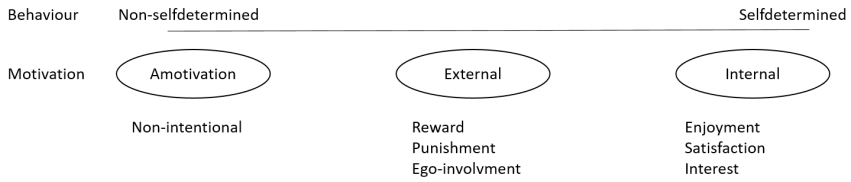


Figure 2.1: The selfdetermination continuum (Adapted from figure 1 in Ryan and Deci (2000))

2.3 Theoretical model and hypotheses

Based on the idea that a behaviour is the result of a pre-identified intention, we focus here on explaining the individual intentions to modal shift from the car to active modes. We build a theoretical model, presented in figure 2.2, to test the relationships between SDM, NSDM and active mobility habits in predicting the intentions of choosing alternatives to the private car. We make assumptions on the way socio-demographic variables (age, gender, income, level of mobility[5], zone of residence and number of owned vehicles) influence the three latent variables.

We suppose that motivations are the main predictor of intentions and do not initially consider habits in the study of this relationship. For both motivations, SDM and NSDM, we expect a positive relation with more motivated individuals having higher intentions to use alternative modes (H1 and H2). These assumptions

[5]We describe the level of mobility of the observed individuals using their occupations. We suppose that an individual is "mobile" in case he has a professional activity or he is, a pupil, a student or an unpaid trainee. We assume that such categories of people will probably make a high number of trips to go to work or to study, etc. In parallel, we suppose that an individual is "less mobile" if he is unemployed, retired or pre-retired, a housekeeper or man and in any other inactive situation.

are grounded on the previously presented literature in which motivations, especially SDM, were positively related to intentions to engage in pro-environmental behaviours and physical activity (eg. Webb et al., 2013; Hagger and Chatzisarantis, 2009).

Aware that yesterday's habits may prevent change in tomorrow's transportation behaviour (Klöckner and Verplanken, 2018), we enrich the first model of the motivation-intention relationship by introducing habits. Traditionally, the studies of the determinants of modal shifting introduce habits as the past choice or automatic choice of the car (eg. Gardner et al., 2020, Ramos et al., 2020). In the present model, we instead introduce the mobility habits as a measure of the automaticity of choosing active mobility. Thus, we expect a positive relation between active mobility habits and intentions to modal shift. We actually consider that the fail to change mobility practices is partly due to a lack of practice of the active modes resulting in less knowledge about the available options other than the private car. This makes it more costly for the individual to start practicing it and creating active mobility habits.

Introducing this variable in the motivation-intention relation would allow us to better understand the interactions between these variables and build the motivational process behind modal shifting. We actually expect that active mobility habits is a mediator between both motivations and intentions (see $H1'$ and $H2'$). This means that being selfdeterminally motivated or non selfdeterminally motivated could not only have a direct effect on intentions to modal shift but also help to build active mobility habits which in turn generates an indirect effect through active mobility habits of motivations on intentions.

Previous studies interested in assessing the motivation-intention relation have generally introduced past behaviour or habits as a direct determinant of intentions or as a moderator influencing other determinants of intentions (Hagger and Chatzisarantis, 2009; Webb et al., 2013). Less is known about the possible effect of active mobility habits on intentions if considered as a mediator of a previously identified relation (i.e here, the motivation-intention relation).

Regarding the socio-demographic variables, we expect that they influence all the latent constructs including the dependent variable of intentions. We expect younger individuals to have higher intentions to modal shift. In the literature, the age effect depends on the specific type of active mode: on the one hand, younger individuals cycle more (Muñoz et al., 2016) and on the other hand, older individuals use public transport more (Ton et al., 2019). In terms of gender, we do not think that we would find a significant difference between male and female to modal shift. Indeed, the literature does not reach a consensus in this regard (De Witte et al., 2013; Best and Lanzendorf, 2005). For the income effect, we expect that a higher

income would influence negatively the intentions to modal shift. Previous studies assessing the income effect on modal choice have identified a significant relation. For example, car owners tend to be higher income populations showing a positive relationship between income and private car use (Tao et al., 2019; De Witte et al., 2013). Besides, the level of mobility which reflects the frequency of trips done in a day related to the occupation is expected to influence negatively the intentions to modal shift. We think that individuals who are more mobile would opt to using the fastest mode of transport which is generally considered to be the car. Referring to the literature, usual car users struggle to consider other options due to generalised misconceptions (Ramos et al., 2020) about the alternatives such as the perceived lack of control for public transport or lack of safety when using the bicycle. The zone of residence is also expected to influence our model. We expect that people who live in urban areas with well-developed transportation network and cycling paths are more likely to have higher intentions to modal shift. Indeed, the review done by De Witte et al. (2013) about the determinants of mobility confirms this idea. Lastly, we believe that having a private vehicle in the household would encourage the individuals to keep using the car instead of changing their practices (De Witte et al., 2013), especially if they have multiple cars.

The hypotheses testing the relation between SDM, NSDM, active mobility habits and intentions are as follows

> H1: Higher selfdetermined motivated individuals have higher intentions to modal shift
>
> $H1'$: ... and having the habits of using active modes is a mediator of this relation
>
> H2: Higher non selfdetermined motivated individuals have higher intentions to modal shift
>
> $H2'$: ... and having the habits of using active modes is a mediator of this relation

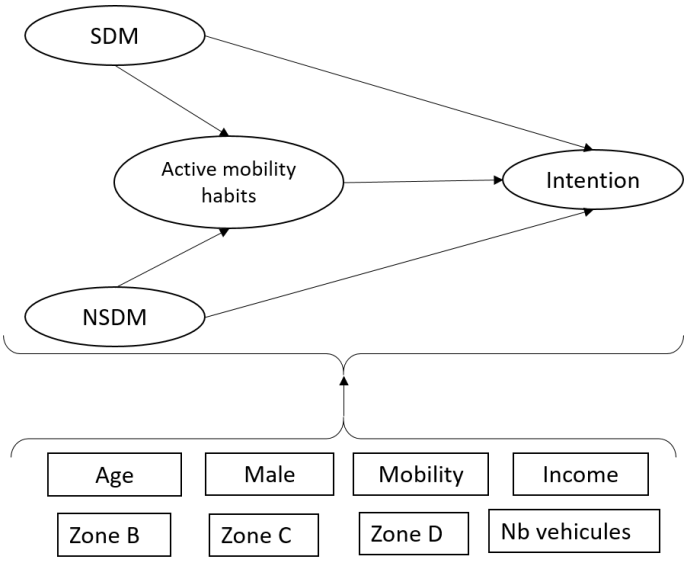


Figure 2.2: The theoretical model

Notes:
SDM = Selfdetermined motivation
NSDM = non selfdetermined motivation

2.4 Data and methods

2.4.1 Participants and procedure

We use original data collected through a phone survey conducted between April and May 2019 within the QAMECS-SHS project[6]. Table 2.1 presents a summary of the descriptive statistics of some socio-demographic variables. We have a sub-sample of 1,033 participants[7] living in Grenoble Metropolitan Area among which 49% are male with 50 years old mean age and around € 2900 mean income. A majority of 65% of the sample are mobile individuals making a high number of trips per day. Besides, most of our sample is composed of individuals living in or close to the city[8], so in zones that are generally well-connected in terms of transportation services and infrastructure (public transport, cycling paths, etc.): 34% live in the city of Grenoble (Zone A), 37% in the adjacent areas called the "Urban heart" (Zone B), 10% live in peri-urban and rural territories (Zone C) and the remaining 19% are residents of Grenoble's neighbouring inter-municipalities (Zone D, Grésivaudan and Voironnais).

[6]Qualité de l'air dans l'agglomération grenobloise: Evaluation de l'environnement, du comportement et de la santé. The project was funded by Ademe (Agence de la transition écologique) and the Metro (Grenoble-Alpes Métropole)

[7]The survey allowed collecting data of 1,304 participants among which 271 are amotivated. These participants are discarded from our analyses since amotivated individuals are supposed to have null intentions while intentions is the dependent variable in the tested model.

[8]See map of the surveyed zones in figure A.2

Table 2.1: Summary of the socio-demographic variables

Variable	Label	Code	Proportion (%)
Male	Gender	=1 if male =0 if female	48.79
Mobility	Level of mobility	=1 if mobile = 0 if less mobile	65.34
ZoneA	Resident of zone A (reference zone)	=1 if resident of zone A (Grenoble city) = 0 if not	33.88
ZoneB	Resident of zone B	=1 if resident of zone B ("Urban heart" of the metropolis) = 0 if not	36.69
ZoneC	Resident of zone C	=1 if resident of zone C (Peri-urban and rural territories) = 0 if not	10.36
ZoneD	Resident of zone D	=1 if resident of zone D (Grésivaudan or Voironnais) = 0 if not	19.07
			Mean (SD)
Age	Age in number of years	Continuous variable	50.10 (18.49)
Income	level of income in €	Continuous variable	2940.12 (1577.05)
Nb vehicles	Number of vehicle per household	Continuous variable	1.41 (1.03)

2.4.2 Measures

Based on the literature, we introduced in the survey the items measuring our variables of interest. Then, we made a series of Exploratory factor analyses (EFA) and Confirmatory factor analyses (CFA), explained in more detail in the next section, to test the robustness of the latent constructs and to build reliable models. A summary of the used items is presented in table D.4 with some descriptive statistics related to the participants' answers.

Intentions We measure the intentions to modal shift by determining the stage-of-change (Biehl et al., 2018) the participant is in. For this, we ask the participant to declare on a 5-points scale whether they 1.do not intend to begin using active modes, 2. are thinking about it, 3. have serious intentions to start using alternatives, 4. already use them at least three time a week or 5. already use them every day.

Behavioural automaticity (active mobility habits) Habits are generally measured using frequency measures or automaticty measures. In our case, we choose to use the latter. Indeed, according to Gardner et al. (2012) and Gardner (2012), measuring habits with automaticity measures is more reliable than just counting frequencies. However, previous studies assessing the relation between our variables of interest measure the past behaviour relying on frequencies (Webb et al., 2013; Hagger and Chatzisarantis, 2009). Testing these relations with automaticity as the measure of habits is thus another contribution of this work. We implement the Self-Report Behavioural Automaticity Index (SRBAI, Gardner et al., 2012) to measure automaticity of choosing active modes as alternatives to the private car. The mea-

sure of active mobility habit is composed of four items with 5-points Likert scales ranging from 1 for "strongly disagree" to 5 for "strongly agree".

Motivations (SDM and NSDM) We measure the individual motivations as two separate latent constructs, distinguishing SDM from NSDM, following the work of Brunet et al. (2015). SDM is composed of five items asking the participants to declare the degree to which their motivations to use alternatives to the car are the result of personal interest, satisfaction and enjoyment (eg. If you intend to use an alternative transportation mode to the car on the majority of your trips, it's mainly because you like it, Q9 in table D.4). This is done using 5-points Likert scales ranging from 1 for "strongly disagree" to 5 for "strongly agree". Regarding NSDM, it is composed of four items asking the participants about the degree to which their motivations to use alternatives to the car are the result of external punishment or reward (eg. If you intend to use an alternative transportation mode to the car on the majority of your trips, it's mainly because people around you criticise you if you do not use an alternative mode, Q13 in table D.4). This is also done using 5-points Likert scales ranging from 1 for "strongly disagree" to 5 for "strongly agree".

Table 2.2: List of items measuring the latent constructs of the model

Latent construct	Adapted from	Item		Scale	Mean (SD)
Intention	Biehl et al. (2018) and Godin (2013)	Q1	Do you use an alternative mode of transportation to the private car for at least 3 trips per week (including weekends)?	1.No, I don't intend to begin, 2.No, I'm thinking about it, 3.No, I seriously intend to start, 4.Yes, at least 3 times a week, 5.Yes, every day or almost every day	4.7 (0.75)
Active mobility habits	Gardner et al. (2012)		Deciding to use an alternative mode of transportation to the car is something :	1=Strongly Disagree to 5=Strongly Agree	
		Q2	That you do automatically		3.58 (1.42)
		Q3	That you do without thinking about it		3.52 (1.44)
		Q4	That you do without having to consciously remember		3.55 (1.42)
		Q5	That you start doing before you realize it		3.15 (1.45)
selfdetermined motivation (SDM)	Brunet et al. (2015)		If you intend to use an alternative mode of transportation to the car on the majority of your trips, it's mainly because	1=Strongly Disagree to 5=Strongly Agree	
		Q6	... you believe it's important		3.82 (1.31)
		Q7	...for the pleasure of using an alternative mode of transportation (e.g., walking, cycling)		3.27 (1.40)
		Q8	... it gives you a plus		3.42 (1.38)
		Q9	... you like it		3.36 (1.36)
		Q10	... for your health		3.51 (1.36)
Non selfdetermined motivation (NSDM)	Brunet et al. (2015)	Q11	... people around you are pushing you to do it	1=Strongly Disagree to 5=Strongly Agree	1.76 (1.12)
		Q12	... you would feel ashamed not to do it		2.05 (1.25)
		Q13	... people around you criticise you if you do not use an alternative mode		1.48 (0.94)
		Q14	... you would feel guilty about not using an alternative mode of transportation		2.25 (1.34)

2.4.3 Data analyses

When studying relationships between latent variables that are measured with observed items, the most appropriate and widely used method is Structural equation Modeling (SEM). The objective of a SEM is to test hypotheses of relationships between several variables of a theoretical model.
To guarantee a well-established and reliable model, we assess the internal consistency of the scales using EFA and CFA, then test the relations between the latent constructs using SEM.

Exploratory factor analyses (EFA) Carrying out an EFA allows us to validate scales of items in a questionnaire and derive a construct (e.g. active mobility habits) for a group of items (e.g. Q2 to Q5). This statistical technique is done following a number of steps (Samuels, 2017) that we describe in more details in appendix B.1.

We start by doing a series of tests verifying the adequacy of doing an EFA on our data (Kaiser-Meyer-Olkin measure of sampling adequacy test, Bartlett's test of sphericity, etc.). The items that we focus on are the questions Q2 to Q14 (see table D.4).

The EFA allowed us to identify 3 latent constructs with a good level of internal consistency (referring to their Cronbach's alpha coefficients): active mobility habits, SDM and NSDM.

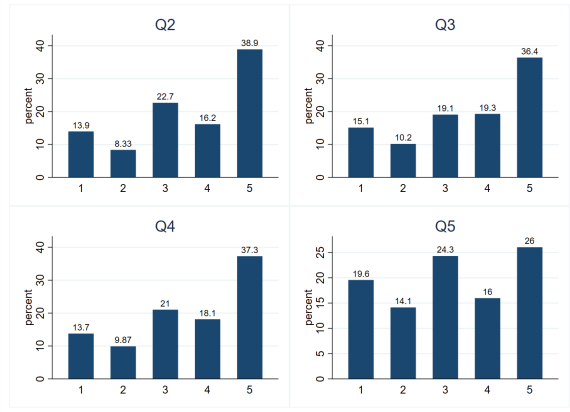
Confirmatory factor analyses (CFA) After the EFA, we move to confirmatory factor analyses (also known as measurement model in SEM). CFA is used to confirm the existence of relations between the constructs and the items that measure them. The relations are usually supported by a theoretical model and this statistical technique intervenes, as its name suggests, to confirm empirically the supposed correlations presented in the theoretical model.

CFA relies on several statistical tests to determine the adequacy of model fit to the data. The model estimated is assessed using model fit indices such as the chi-square test, the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI) and the Tucker–Lewis index (TLI), etc. If the model is found to be well-adjusted to the data, we can move to structural equation modeling.

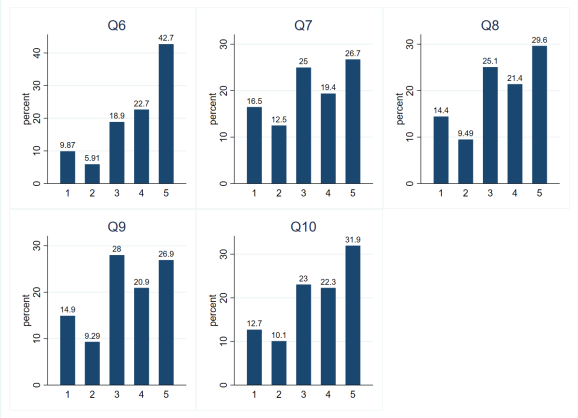
When estimating the model it is important to choose the appropriate estimation method to the type of data. In general, CFA is done using the Maximum Likelihood (ML) estimation method. However, using this method is only allowed when the data is continuous and has a normal distribution. Since our questions are 5-points Likert scales, the data that we are analyzing is ordinal and does not follow a normal distribution[9]. Figure 2.3 presents the distribution of the answers to the used items.

[9]Following the results of the tests of normality of data Shapiro–Wilk (Shapiro and Wilk, 1965)

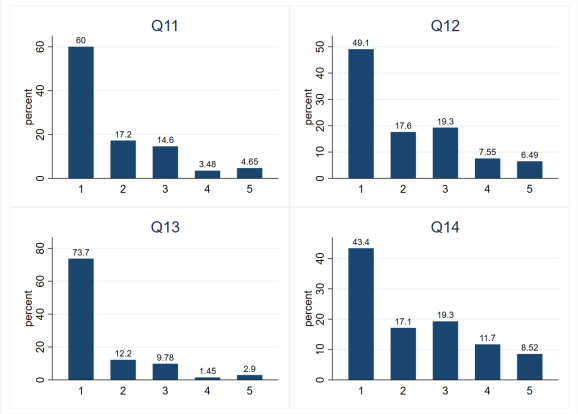
Thus, using ML is not suitable (Rhemtulla et al., 2012; Bouscasse et al., 2018). Instead, we choose the diagonally Weighted Least Squares method with a Mean and Variance correction (WLSMV) which was demonstrated to perform better with ordinal data (Li, 2014).



(a) Active mobility habits (Q2-Q5)



(b) Selfdetermined motivation (Q6-Q10)



(c) non selfdetermined motivation (Q11-Q14)

Figure 2.3: Distribution of the answers to the items Q2 to Q14

Mediation analyses with structural equation modeling Mediation analyses consists of supposing that there is a variable, called a mediator, that explains the

relationship between two other variables. This kind of method helps to understand a decision process and visualise the contribution of each one of its elements. In the present study, we build a model to test the mediating role of active mobility habits in the motivations-intention relation. We control for the effects of the socio-demographic variables.

The mediation analysis is done following three main steps described by Baron and Kenny (1986). These steps consist in building three sub-models for each studied mediation relation. First, a model involving only the independent (i.e SDM and NSDM) and the dependent variable (i.e Intentions) is estimated. If this relation is significant, a second regression is done to verify the significance of the relation between the independent variable (SDM and NSDM) and the mediator (active mobility habits). A final regression is done combining the mediator, the independent and the dependent variables. For many years, these steps were performed using multiple regression analyses. But it has been shown that this method is not very suitable for mediation analyses because it presumes the directions of the causal relationships. Instead, SEM was demonstrated to be more appropriate for mediation analyses. According to Gunzler et al. (2013), the advantages of using SEM are mainly related to the ease of interpretation and estimation in testing mediation hypotheses which justifies our choice of this method to carry out our analyses.

When doing mediation analyses, it is important to start by verifying the significance of the direct effect of the independent variable on the dependent variable. If it is significant, we add the mediator to the model. The direct effect is then expected to be reduced since some of the effect is now explained by the mediator. If the direct effect is reduced but stays significant, the mediation effect is called "partial mediation". But if the direct effect is reduced and becomes non-significant, then the mediation is called "complete mediation" or "full mediation" (Awang, 2012). We test the significance of the indirect effects using Sobel test (or Delta method) (Sobel, 1982).

2.5 Results

We build SEM testing the mediation effect of active mobility habits in the motivation-intention relation, aiming to better understand the defining determinants of modal shift intentions. SEM is a combination of CFA and regression models used to understand the paths between the latent constructs. The following section is a presentation of the results of the analyses that we carried to build and test our model helping us respond to our research question. We start by presenting the EFA and the CFA (measurement model) results. Then, the results of the mediation analyses.

2.5.1 Exploratory factor analyses (EFA)

Following the steps detailed in appendix B.1, we performed an EFA of the items Q2 to Q14. As previously mentioned, we identified three factors presenting good levels of internal consistency based on their Cronbach's alpha coefficients ($\alpha > 0.6$). Table 2.3 presents a summary of the results of the EFA which allowed to identify three factors without dropping any of the included items. The first factor ($\alpha = 0.88$) refers to active mobility habits and is composed of items Q2 to Q5 with factors loading ranging from 0.78 to 0.87. The second factor ($\alpha = 0.78$) refers to SDM including the items Q6 to Q10 with factors loading ranging from 0.64 to 0.73. The final factor ($\alpha = 0.68$) refers to NSDM and is composed of items Q11 to Q14. The factors loading of these items range from 0.66 to 0.75.

Table 2.3: Results of the exploratory factor analyses of the items Q2 to Q14

	Questions	**Factor Loading**	α
Factor 1 : active mobility habits	Q2. That you do without having to consciously remember	0.87	*0.88*
	Q3. That you do without thinking about it	0.86	
	Q4. That you do automatically	0.85	
	Q5. That you start doing before you realize it	0.78	
Factor 2 : SDM	Q6. ... you like it	0.73	*0.78*
	Q7. ...for the pleasure of using an alternative mode of transportation	0.72	
	Q8. ... for your health	0.71	
	Q9. ... you believe it's important	0.64	
	Q10. ... it gives you a plus	0.64	
Factor 3 : NSDM	Q11. ... you would feel ashamed not to do it	0.75	*0.68*
	Q12. ... people around you are pushing you to do it	0.74	
	Q13. ... you would feel guilty about not using an alternative mode of transportation	0.71	
	Q14. ... people around you criticize you if you don't use an alternative mode	0.66	

Notes:
SDM = selfdetermination motivation, NSDM = non selfdetermination motivation
All chosen factor loadings are above 0.4
α: Cronbach's alpha coefficient

2.5.2 Confirmatory factor analyses (CFA)

Using the three latent constructs identified through the EFA, we carry out the factor analyses by doing a CFA. The used estimation method is WLSMV since we are manipulating ordinal data. The model tested is presented in figure 2.4.

To empirically judge the quality of a model using CFA, we check its fit indices. In our case, we have a chi-square test chi2(62)= 449.470 with p-value < 0.05. If p-value is greater than 0.05, this indicates that there is little difference between the expected and the observed covariance matrices. A more informative index is the Root Mean Square Error of Approximation (RMSEA) which is here equal to 0.078. This suggests having an acceptable fit of the data to the model since we have a value between 0.05 and 0.08 (Hu and Bentler, 1999; Kaplan, 2008). The values of the comparative fit index (CFI) and the Tucker–Lewis index (TLI), 0.972 and 0.965 respectively, are above the recommended threshold of 0.95 which also means that our model fits well our data. The model presented here supposes correlations only between the latent variables. Correlations between the residuals of the items could also exist by verifying the modification indices[10] which could further improve our model fit.

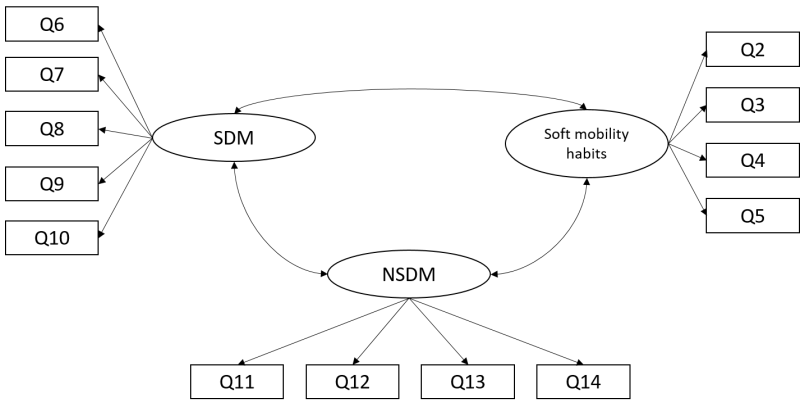


Figure 2.4: Model tested through confirmatory factor analyses

2.5.3 Mediation analyses using SEM

We conduct the mediation analyses following the steps of Baron and Kenny (1986) by creating sub-models that are summarised in table 2.4. Model M1a tests the direct effect of both motivations on intentions. Model M1b tests the indirect effect of SDM on intentions through active mobility habits. Model M1c tests the indirect effect of

[10] A modification index is the χ value, with 1 degree of freedom, by which model fit would improve if a path was added or eliminated from a path model. Usually, values larger than 10 could be followed. However, adding these paths should not be justified only by the high level of the modification index but also theoretically supported.

NSDM on intentions through active mobility habits. Besides, M1d tests the indirect effect of SDM and NSDM on intentions through active mobility habits. The results of the estimations of these models are presented in table 2.5.

Table 2.4: Summary of the estimated models

Hypothesis	**Tested effect**	**Models**
H1: Higher selfdetermined motivated individuals have higher intentions to modal shift	Direct	M1a
H1': ... and having the habits of using alternative modes is a mediator of this relation	Indirect	M1b & M1d
H2: Higher non selfdetermined motivated individuals have higher intentions to modal shift	Direct	M1a
H2': ... and having the habits of using alternative modes is a mediator of this relation	Indirect	M1c & M1d

The first simple regression, M1a in figure 2.5, assessing the direct effect of the two types of motivations demonstrates a significant effect of SDM (0.118, p-value= 0.047) but not of NSDM (-0.055, p-value=0.359) on the intentions to modal shift.

Introducing the active mobility habits as a possible mediator, model M1b in figure 2.6, the results show a very significant indirect effect ($0.187 = 0.591 \times 0.315$, p-value=0.000) of SDM on intentions going through the habits. However, the direct effect of SDM on intentions becomes non significant (-0.088, p-value=0.225). This means that we are in the case of a full mediation effect.

Regarding NSDM, since we have a non significant direct effect of this type of motivation on intentions, it is not possible to carry on the mediation analysis evaluating the indirect effect of NSDM through active mobility habits. Thus, we discard the model M1c and we do not present its results in table 2.5.

We complement the model M1b by introducing the NSDM to take into account the correlation that may exist between the two types of motivation in determining the intentions (see model M1d presented in figure 2.7). We notice that the direct effects of both motivations on intentions remain non significant. However, these motivations influence significantly the active mobility habits. The SDM are actually positively associated to stronger active mobility habits (0.648, p-value=0.000) contrary to NSDM which are negatively associated to these habits (-0.148, p-value=0.000).

This results in indirect effects of motivations on intentions through habits as the mediator. The indirect effect of SDM on intentions is significant and positive ($0.203 = 0.648 \times 0.313, p - value = 0.000$). Whereas NSDM has a significant and negative indirect effect on intentions ($-0.046 = -0.148 \times 0.313, p - value = 0.003$). Having significant indirect effects and non significant direct effects means that active mobility habits fully mediate the relation between motivations and intentions (see

table 2.6).

Looking to the effects of the socio-demographic variables on each latent construct in the most exhaustive model (model M1d), we find that age influences significantly uniquely the intentions to modal shift: older participants are less likely to have higher intentions to modal shift (-1.099, p-value<0.1). This result contradicts the ones presented in the meta-analysis of Aldred et al. (2017) who found that older individuals have lower preferences for the private vehicle, so relying more on active mobility. The refrain of our older participants from having intentions to modal shift could be related not only to latent factors influencing the level of these intentions but also to health and urban design factors, as mentioned in the study of Klicnik and Dogra (2019).

Furthermore, our results show that the zone of residence influences all the constructs but in different ways. Considering zone A (Grenoble city) as the reference zone, being a resident of a non-central zone is negatively associated with SDM (zone B: -0.049, zone C:-0.119, zone D:-0.103) and active mobility habits (zone B: -0.039, zone C:-0.094, zone D:-0.081). For both constructs, we notice a sort of a gradient: Negative coefficients are higher for zone C compared to zone B. This gradient is inverted when reaching zone D. An explanation may be that residents of zone D make less frequent trips to Grenoble city so they are less sensitive to the distance influencing their SDM and active mobility habits. For the two other zones (B and C), the negative effect may be larger because in these zones the transportation network is less developed compared to zone A. Thus, usually using alternatives to the car and being individually motivated to do so is less likely. In contrast, we find that living further away from zone A is positively related to higher NSDM. This is true especially for residents of zone D (0.087, p-value<0.05). Residents of zones closer to zone A do not feel the social pressure and shame of not using alternatives to the car, whereas residents of zone D could be motivated to modal shift through this type of motivation. The estimation results also demonstrate that being a resident of further zones away from Grenoble city is negatively associated with intentions to modal shift. This effect is the strongest when comparing zones B to A and decreases as one moves away from zone A. This could also be related to the quality of the transportation network in the zones. Since the network in zone C is less developed, people usually consider less the alternatives to the car in their modal choice. Thus, intentions and zones away from the city center are negatively associated.

Car ownership is negatively associated with SDM (-0.092, p-value<0.01) and active mobility habits (-0.073, p-value<0.01). This result emphasizes the idea that having a car in the household is a barrier to considering alternatives to the car (Tao et al., 2019).

Lastly, the gender, the individual's level of mobility and his income level do not

influence significantly any of the studied latent constructs.

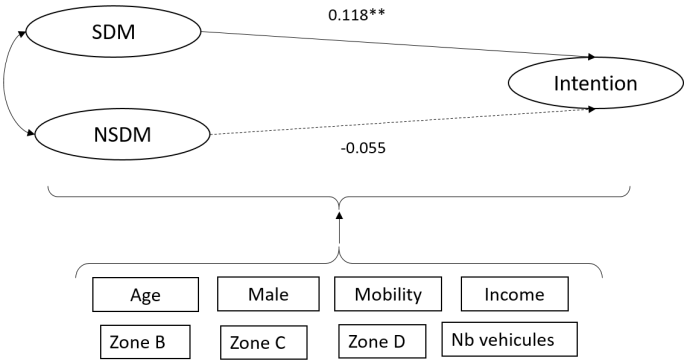


Figure 2.5: Standardised regression weights of model M1a

$^{**}p < 0.05$; $^{***}p < 0.01$
RMSEA = 0.037; SDM = selfdetermined motivation; NSDM = non selfdetermined motivation

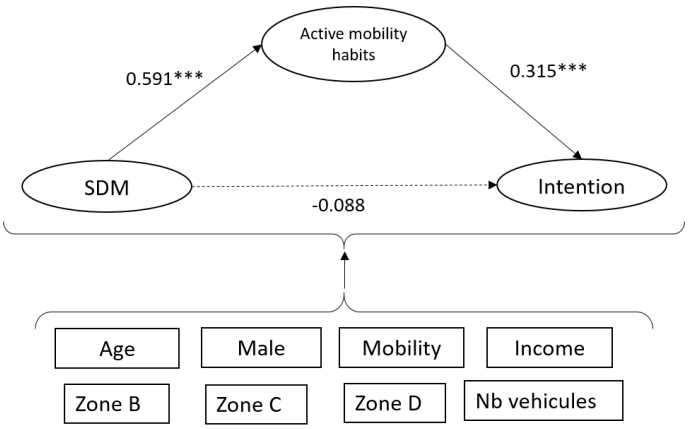


Figure 2.6: Standardised regression weights of model M1b

$^{**}p < 0.05$; $^{***}p < 0.01$
RMSEA = 0.033; SDM = selfdetermined motivation; NSDM = non selfdetermined motivation

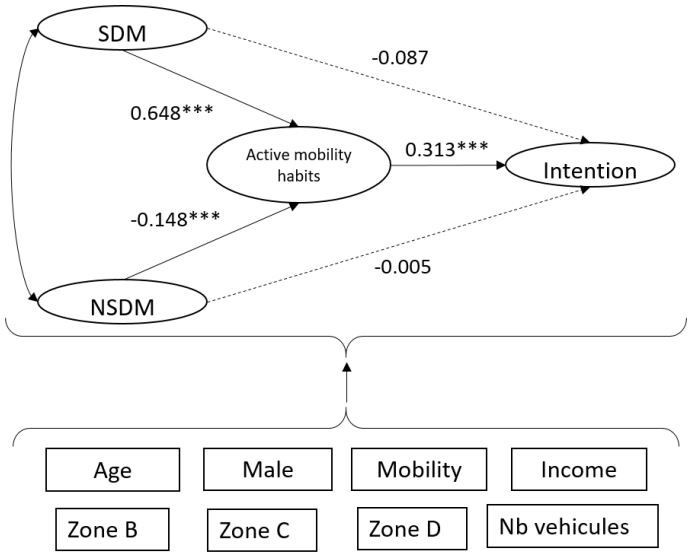


Figure 2.7: Standardised regression weights of model M1d

$^{**}p < 0.05$; $^{***}p < 0.01$
RMSEA = 0.045; SDM = selfdetermined motivation; NSDM = non selfdetermined motivation

Table 2.5: Estimation results

Dependent variable	Explanatory variable	M1a	M1b	M1d
SDM	Male	-0.070	-0.070 (0.046)**	-0.036 (0.033)
	Age	0.924 (0.008)***	0.934 (0.007)***	0.228 (0.005)
	Age^2	-0.822 (0,000)***	-0.833 (0.000)***	-0.206 (0.000)
	Income	0.065 (0.000)*	0.066 (0.000)*	0.019 (0.000)
	Mobility	0.047 (0.073)	0.045 (0.065)	0.033 (0.048)
	ZoneB	-0.030 (0.063)	-0.029 (0.056)	-0.049 (0.041)*
	ZoneC	-0.059 (0.063)	-0.066 (0.081)*	-0.119 (0.061)***
	ZoneD	-0.083 (0.092)**	-0.088 (0.070)**	-0.103 (0.049)***
	Nb vehicles	-0.076 (0.027)**	-0.078 (0.024)**	-0.092 (0.016)***
NSDM	Male	-0.007		-0.015 (0.038)
	Age	-0.537 (0.007)**		-0.412 (0.006)*
	Age^2	0.492 (0.000)**		0.381 (0.000)*
	Income	-0.004 (0.000)		0.001 (0.000)
	Mobility	0.018 (0.060)		0.023 (0.054)
	ZoneB	0.066 (0.051)		0.065 (0.046)
	ZoneC	0.028 (0.081)		0.033 (0.073)
	ZoneD	0.089 (0.063)**		0.087 (0.058)**
	Nb vehicles	-0.077 (0.022)*		-0.071 (0.021)*
active mobility habit	SDM		0.591 (0.045)***	0.648 (0.045)***
	NSDM			-0.148 (0.059)***
	Male		0.012 (0.054)	-0.028 (0.033)
	Age		-0.555 (0.009)***	0.180 (0.005)
	Age^2		0.487 (0.000)***	-0.162 (0.000)
	Income		-0.037 (0.000)	0.015 (0.000)
	Mobility		0.009 (0.062)	0.026 (0.048)
	ZoneB		-0.073 (0.062)**	-0.039 (0.041)*
	ZoneC		-0.167 (0.104)***	-0.094 (0.061)***
	ZoneD		-0.117 (0.084)***	-0.081 (0.049)***
	Nb vehicles		-0.081 (0.031)**	-0.073 (0.016)***
Intention	SDM	0.118 (0.085)**	-0.088 (0.117)	-0.087 (0.122)
	NSDM	-0.055 (0.109)		-0.005 (0.111)
	active mobility habit		0.315 (0.077)***	0.313 (0.079)***
	Male	-0.052 (0.097)	-0.057 (0.097)	-0.048 (0.096)
	Age	-1.134 (0.018)***	-0.912 (0.018)***	-1.099 (0.017)***
	Age^2	1.148 (0.000)***	0.953 (0.000)***	1.119 (0.000)***
	Income	-0.054 (0.000)	-0.041 (0.000)	-0.053 (0.000)
	Mobility	0.098 (0.128)	0.095 (0.130)	0.091 (0.128)
	ZoneB	-0.186 (0.130)***	-0.167 (0.128)***	-0.172 (0.128)***
	ZoneC	-0.171 (0.171)***	-0.121 (0.176)**	-0.135 (0.174)***
	ZoneD	-0.115 (0.150)**	-0.084 (0.149)	-0.087 (0.149)
	Nb vehicles	-0.071 (0.058)	-0.042 (0.057)	-0.046 (0.057)
Covariances	SDM ∼∼NSDM	0.459 (0.026)***		0.429 (0.026)***
	Q6 ∼∼Q10	-0.321 (0.081)		-1.219 (0.115)*
	Q5 ∼∼Q9	0.427 (0.037)***		0.450 (0.040)***
	Q8 ∼∼Q12	0.357 (0.022)***	0.244 (0.025)***	0.300 (0.023)***
	Q7 ∼∼Q13		0.190 (0.025)***	
Goodness Of Fit	RMSEA	0.037	0.033	0.045
	TLI	0.987	0.996	0.986
	CFI	0.974	0.991	0.974

Notes:
SDM = selfdetermination motivation, NSDM = non selfdetermination motivation
*$p < 0.1$;** $p < 0.05$; ***$p < 0.01$
Standard error between parentheses

Table 2.6: Summary of the mediation results (M1d)

Hypotheses	Estimate (Standardised)	p-value	Results on hypotheses	Results on mediation
SDM has a significant effect on active mobility habit	0.648	0.000	Supported	
NSDM has a significant effect on active mobility habit	-0.148	0.000	Supported	
active mobility habit has a significant effect on intention	0.313	0.000	Supported	Full mediation
SDM has a significant effect on intention	-0.087	0.288	Rejected	
NSDM has a significant effect on intention	-0.005	0.924	Rejected	

2.6 Discussion and conclusion

In this chapter, we assess the motivation-intention relation assuming that intentions to modal shift are the result of SDM and NSDM. We also investigate the role of active mobility habits in this relation as a possible mediator. To this end, we run SEM including these latent constructs and controlling for the effect of socio-demographic determinants.

Our results are consistent with the findings of previous studies. We find, without considering habits, significant but small direct effect of motivations on intentions. This is similar to the result presented by Hagger and Chatzisarantis (2009). Additionally, the distinction between the two constructs SDM and NSDM confirms that this effect on intentions comes mainly from SDM. This is similar to the findings of Webb et al. (2013) who identified a significant direct effect of SDM on intentions and behaviour to save energy but NSDM did not predict the intentions nor the behaviour.

The identified direct effect becomes non significant when including active mobility habits as a mediator of the motivation-intention relation. Thus, active mobility habits overpower the direct effect of SDM on intentions. This confirms the high association between habits and intentions, especially when they are going in the same direction as mentioned by Gardner et al. (2020).

However, both types of motivations seem to be powerful predictors of mobility habits but with different signs. NSDM is negatively associated with active mobility habits meaning that being socially pressured to adopt alternative modes to the car reduces the habits of using active modes. Whereas, SDM is positively associated with active mobility habits meaning that those who personally enjoy using active modes are more likely to develop a habit for that modal choice. These results also go along previous findings. For instance, Gardner and Lally (2013) identified that individuals are more likely to regularly engage in physical activity if they are more autonomously motivated (i.e. SDM) than those externally motivated (i.e. NSDM).

In light of these results, public recommendations could be provided. First, public authorities need to increase people's SDM to use active modes. This could be

done through measures allowing for individuals to feel more in control of their own decisions and better perceive the utility of changing their mobility practices. Such measures could take the form of public informative campaigns about the positive consequences of modal shifting on improving the environment or reducing health risks. This is what we study in the next chapter of the present thesis and we show that providing information about reduced risk of developing cardiovascular disease thanks to modal shifting increases the probability of people choosing active modes (Bouscasse et al., 2022b). Another example of a public measure that stems from our work is the improvement of cycling infrastructure. Safer cycle paths would change perceptions about the unsafety of cycling and make cycling more enjoyable.

Second, the results about NSDM and its negative effects on active mobility habits and intentions suggest that interventions based on guilt or shame should be avoided. For example, using messages communicating the negative consequences of using the private car would actually be counterproductive resulting in less modal shifting. We recommend rather focusing on communicating positive messages about the benefits of modal shifting.

Third, these results indicate to public authorities the importance of considering habits in the design of behaviour change interventions. The strong effect identified for habits suggests the need to find ways to disrupt undesirable habits. In parallel, there is a need to promote the construction of habits of the desired behaviour (here, active mobility). This could take different forms such as giving free test days for the city bicycle and public transport network or help usual car users discover electric bicycles as a fast and not physically tiring alternative to commute on relatively long distances.

The present work has provided more clarity on how desirable habits are influenced by motivations: There is a strong link between habits and the individual's internal beliefs and attitudes rather than the external pressures (social or institutional) that the individual may endure from his environment.

Some limitations with the present work should be mentioned as well as some possible future avenues of research. First, our results highly depend on the way we measured our latent variables. Even though we based our choice of measures on the literature and tested their robustness, using other scales could give different results than the ones found here. Second, we made a distinction between two types of motivations with the SDM having more significant effects. Our results do not show a significant effect of NSDM on intentions. The NSDM may be linked to the pressure that family, friends or professional environment may exert. However, the entourage may also be linked with SDM having a positive effect on intentions to modal shift. If an individual has a friend that uses the public transport instead of the car to commute, this person may choose the public transport not necessarily

because of the pressure felt from this friend but because he enjoys the ride with them. Lambotte et al. (2022) actually show that the professional network has a significant impact on the choice of active modes. It would therefore be useful to conduct further research on the role of the entourage and the motivations in the choice of alternative modes of transport to the car.

Third, our work was an attempt to implement the SDT in the study of mobility behaviour, when it is usually used in physical activity and health studies. However, our models could be extended and tested with other interesting latent and observable variables (eg. environmental concern, existing infrastructure) that may interact with the motivations and habits in defining the intentions. The models tested in this chapter are applied to data from mobility behaviours in the Grenoble region, which presents a certain number of specificities in terms of the deployment of transport infrastructures, in particular bicycle paths, and physical activity practices. It would be useful to replicate these models in other urban contexts, with populations with different socio-demographic characteristics. Lastly, our study was conducted in 2019 before the COVID-19 world pandemic. This external shock has demonstrated a significant effect on changing the transportation behaviour (Campisi et al., 2020; Kalter et al., 2021). However, less is known about the long term effect of the pandemic and whether these changes are long lasting. Thus, making a comparative study with post-pandemic data should be conducted to assess our model and compare its validity before and after this crisis.

Chapter 3

Is the impact of transport modes on health an individual determinant of transport mode choice?

Jointly done with Hélène Bouscasse [1] , Sandrine Mathy [2] and Carole Treibich [2]

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Abstract

High modal share of the private car has important health consequences through an increase of cardiovascular or pulmonary diseases. This increase in morbidity and mortality is due to two different mechanisms: air pollution (particularly fine particulate matter ($PM_{2.5}$)) and sedentary lifestyles (lack of physical activity in our mobility behaviour). In this chapter, we try to evaluate the extent to which information on the impact of mode choice on public or individual health influences our mobility. In other words, does knowing that taking the car increases the risk of developing cardiovascular diseases for the user, through lack of physical activity, and for his co-citizens, through air pollution, have an influence on the choice of alternative modes to the car? We address this question collecting original data in the Grenoble metropolitan area (France) and implementing a Stated Preferences survey. Respondents were presented different scenarios varying depending on mode (car, public transport and cycling), travel time, cost and associated cardiovascular risks. We find that information on health risks related both to air pollution and to lack of physical activity influence participants modal choice's intentions with positive willingness to pay to reduce individual and public risks. Given the current modal share, our results indicate that decision makers could play on both the individual and public health impact of modal choices to encourage citizens to reduce car usage.

Keywords: Health impact, mode choice, discrete choice model, cardiovascular risk

3.1 Introduction

Transport mode choice is a major health issue. First, road transport is among the main contributors to $PM_{2.5}$ emissions and exposure, particularly in urban areas. Air pollution has major and proven effects on mortality and morbidity, mainly through cardiovascular and respiratory health (Hamra et al., 2014; Pope III et al., 2004; WHO, 2016). Exposure to ambient $PM_{2.5}$ annually causes an estimated 4.2 million deaths worldwide (Cohen et al., 2017) and 417,000 annual death cases in Europe (Agency, 2020). In France, about 40,000 people would prematurely die each year due to ambient anthropogenic $PM_{2.5}$ exposure (Medina et al., 2020). Recent work on the oxidative potential of particles (which seeks to link the chemical composition of particles according to their sector of emission and the oxidative impact on respiratory functions) tends to suggest that particles originating from the transport sector could be particularly harmful to the body (Weichenthal et al., 2016; Borlaza et al., 2021a,b; He et al., 2021).

Action on the transport sector is thus essential to significantly reduce health impact of pollution. Bouscasse et al. (2022a) show that it is possible to divide by three the premature mortality due to $PM_{2.5}$ in the Grenoble conurbation by acting jointly on the two main emitting sectors, namely road transport and wood heating. In addition to replacing all inefficient wood heating with pellet stoves it would also be necessary to strongly reduce the number of kilometers traveled by car. Modal shifts has thus an important role to play. Many articles already highlight the health benefits of active mobility (walking, conventional cycling, electrically assisted cycling or even public transports) at the individual level induced by physical activity (Oja et al., 2011; Tainio et al., 2016; Bourne et al., 2018; Hanson and Jones, 2015) however a major lesson of Bouscasse et al. (2022a) is to show that health benefits linked to physical activity may even be greater than the health benefits linked to the reduction of pollution.

The existence of individual health co-benefits of pollution reduction through the development of active mobility and physical activity can be a relevant lever for the adoption of sustainable transport modes. Yet, determinants of behaviour change in the mobility sector seem multidimensional (De Witte et al., 2013) and particularly difficult to achieve (Gossling, 2017) or particularly dependent on environmental-friendly attitudes (Bopp et al., 2011). On the one hand, the health benefits of physical activity obtained thanks to changes in transport modes are a private good that improves the health of those who are physically active and that is not conditional on the actions of other people. On the other hand, pollution reduction actions are considered as a contribution to a public good and may exhibit free rider mechanisms. However, social norms and conformity desire are also likely to play a role in

the individual's modal choices. Lambotte et al. (2022) highlight, for instance, the existence of peer effects at the work place regarding active transport mode choices. These opposing effects make the analysis all more complex.

This characteristic of combined contribution to a public good and a private good concerns other changes in pro-environmental behaviour, such as purchasing organic food and vegetarianism, thermal retrofit of housing (which, in addition to contributing to greenhouse gas mitigation, can have positive health impacts through the reduction of dampness and mold). The literature shows that the altruistic motivation of contributing to the production of a public good is not sufficient to drive changes, particularly because of the free rider problem, whereas the more selfish motivation of improving one's own health can have a leverage effect on these behavioural changes. Consumer preferences for natural and regionally produced beef are shown to be motivated by a combination of perceptions of personal benefits and altruistic factors (Umberger et al., 2009). Willingness to buy organic food showed that individual health impacts constitute a more important argument than environmental impacts (Honkanen et al., 2006). Amelung et al. (2019) report a higher mean willingness to adopt food and housing mitigation actions when providing information on individual health effects of sectoral actions to mitigate greenhouse gas emissions. While these authors do not observe such result in the transport sector, Sottile et al. (2015a) highlight that aspects associated with individual health (stress) appear to have a greater influence on travel choice than environmental aspects (CO_2 emissions).

Further, the way in which information about the effect of behaviours on health is presented is a key element. There are two strands of literature that address this dimension: the literature on consumer choices and daily behaviours that can impact our health (diet, physical activity) and the literature on preventive behaviours and health treatment choices (cancer screening).

The literature on how health considerations can influence health related daily behaviours is only rarely based on direct tangible and quantified health outcomes. Shepherd et al. (2005) and Paul and Rana (2012) consider general health benefits as a determinant of organic food consumption without specifying or quantifying specific elements of health benefits. Using a Stated Preferences survey, Asselin (2005) reports that willingness to pay for eggs with health value-added characteristics (omega-3, vitamins) increases with health consciousness and health behaviour. Herens et al. (2017) demonstrate a willingness to pay for physical activity, related to "perceived health". Exceptions are Johnson et al. (2000) and Amelung et al. (2019) who provide quantified information on health impacts. The former measures the willingness to pay for improved respiratory and cardiovascular health, considered as a reduction of symptoms, episode duration, activity restrictions, and cost. As for Amelung et al. (2019), they classified the likely impact on life expectancy using four categories:

substantial (> 3 months increase); moderate (estimated increase in life expectancy $1-3$ months); small (estimated increase in life expectancy < 1 month); and negative (a decrease in life expectancy).

In order to better understand how health impacts can be taken into account in behavioural choices, it can therefore be instructive to rely on tangible and quantified elements of health risks. The medical literature on patients' understanding of decisions about preventive behaviours or treatments is full of insights in this regard. In such contexts, patients are presented with risk statistics and asked to make comparisons between the risks and benefits of multiple options and to make informed medical decisions. However, many people have low numeracy skills making the cognitive demands even greater whenever, as it is often the case, patients are presented with risk statistics and asked to make comparisons between the risks and benefits of multiple options and to make informed medical decisions (Fagerlin et al., 2011). Visual presentations of risk information can be useful. Fagerlin et al. (2011) make recommendations using pictograms to communicate risk and benefit information related to health risks. Presenting probabilistic information in graphical format, in addition to numerical format, increases people's understanding and may affect their decision making (Tait et al., 2010). A growing body of research (Fagerlin et al., 2005; Zikmund-Fisher et al., 2008; Hawley et al., 2008) has conclusively shown that when communicating individual statistics, pictograms are more quickly and better understood than other graphical formats and can help to prevent patients from being biased by other factors. Schapira et al. (2001) evaluated risk communication formats related to breast cancer. They show that graphic discrete frequency formats using highlighted human figures had greater salience than continuous probability formats using bar graphs.

Beyond these issues of understanding risk statistics, the framing of the information is also important (Ahmed et al., 2012; Edwards et al., 2001). Howard and Salkeld (2009) showed with a discrete choice experiment within the context of screening preferences for colorectal cancer that attribute framing (e.g., cancers found vs. cancers missed) significantly influenced estimates of WTP. Grisolía et al. (2018) designed a discrete choice experiments (DCEs) to analyse the trade-off between lifestyles, defined in terms of diet and exercise, and reduction in cardiovascular disease mortality risk. They set three ways of framing an identical benefit: as a reduction in mortality risk from cardiovascular disease, as an increase in months of life expectancy, and as an increase in the probability of reaching an individual's full lifespan. They conclude that the most effective way of communicating these cardiovascular health benefits is using an increase in life expectancy, since with this frame individuals are more inclined to state that they would change to a healthier lifestyle. Such results on the way health benefits are presented is interesting to

combine with the Tversky and Kahneman (1991) experiments where they show that decision makers tend to underestimate gains and overestimate losses.

It is necessary that health risks considered in a DCE are not only understandable but also appropriable by the respondents to a survey, i.e. that they feel concerned. Therefore, if the objective is to study the impact of health benefits related information on the desired behaviour, it may be more relevant to refer to the impact of the behaviour on morbidity rather than on mortality or on gains in months of life expectancy in the general population. The prospect of one's own death is something one prefers not to even mention and this may make respondents uncomfortable. Talking about mortality can also be considered as something that will happen anyway but in a very long time. On the contrary, the impact on diseases that are widespread in the general population and that can affect everyone in the short, medium or long term (such as cardiovascular diseases) is probably more appropriate. The decrease in the risk of developing cardiovascular disease is a common outcome of pollution control measures and of active mobility development. This health benefit is all the more relevant to consider given that about 30% of individuals in the general population will develop a cardiovascular disease in their lifetime (Inserm, 2018). Therefore, we can expect that everyone feels concerned about such health issue.

This chapter aims to assess the extent to which information on individual health benefits through physical activity and for the population as a whole through pollution related to the use of active modes can impact modal choices. We thus develop a Stated Preference survey (i.e. a discrete choice experiment, DCE) on transport mode choices by taking into account the usual determinants (travel time and cost) but also health determinants. The first health determinant refers to the risk of developing cardiovascular diseases as a function of the exposure to pollution induced by the choice of transport mode and the second one evaluates the impact on the risk of cardiovascular disease related to physical activity induced by the choice of transport mode. In order to ensure that the reduction in health risks induced by alternative modes to the car is understood, we have used pictograms. To facilitate the respondent's choice between the scenarios presented in the DCE, a personalised route (regularly undertaken by the respondent) is considered.

The main original contributions of this paper to the literature are fivefold. Firstly, it takes an original approach to modal choice as a health related choice, thus bridging the gap between the literature on modal choice in transport and the literature on health preventive behaviours. Secondly, we are not only interested in the collective health dimension through air pollution but also in individual health, by considering the modal choice as a choice of physical activity. This also allows us to mobilise the literature on physical activity motivations. Thirdly, we look at

the dual motivation (individual and collective) linked to the adoption of a behaviour with a quantitative approach, by investigating the link between behaviour and quantified morbidity risk, and not only qualitative levels, which has up to now not be done in the literature as far as we know. Fourthly, in addition to analysing how clearly quantified risks affect behaviours, we also model how they are perceived by the individuals and how this affects their behaviour and willingness to pay. We therefore combine the behavioural economics literature on risk with the literature on discrete choice models, contributing to a still scarce literature. Fifthly, we question the influence of conformity and the free rider problem on the collective health dimension of modal choice. Let us note that the last three contributions also allow us to contribute to the DCE literature by proposing solutions to present the notion of health risks in an understandable way and by introducing a framing effect.

The remaining of the chapter is structured as follows: section 2 presents the survey protocol and data, the model framework is described in section 3 and section 4 displays and discusses the results. Concluding ideas are in section 5.

3.2 Survey protocol and data

3.2.1 Discrete choice experiment design

We designed a DCE. The originality of the proposed design lies in the fact that we focus on the impact of health concerns and distinguish altruistic motivations related to public health (impact of the mode of transport on pollution and *in fine* on average population health) from selfish motivations related to individual health (impact of walking or cycling instead of driving on its own physical activity and its own health).

Each interviewee was asked to report a trip she makes on a regular basis, this through a map of the Grenoble Metropolitan Area divided in 876 small zones (see appendix C.1 for an example of the map). We asked our participants to consider this particular trip when answering to the DCE. We propose three modes of transport (car, public transport, cycling[3]) to make the regular trip.[4] We characterise each mode by travel time, travel cost and two sanitary risks expressed as risk of developing a cardiovascular disease (cf. Table 3.1).

Regarding the two health attributes, the probabilities presented in the DCE refer to Arterial Hypertension which is the most frequent chronic disease in France

[3]Respondents were asked to indicate whether they preferred an electrically assisted bicycle or a conventional bicycle. This preference was taken into account in the scenarios that were then proposed to them.

[4]If the distance of this declared trip is below three kilometers, we added the walking option. However, the sub-sample of respondents who have a reference trip below three kilometers are not considered in this chapter.

(Inserm, 2018). More precisely, 30% of adults will be affected by a cardiovascular disease during their lifetime. The attribute concerning physical activity of each mode corresponds to the absolute risk of developing a cardiovascular disease if the trip is made with a given mode on a regular basis, considering the distance done and the mode-specific intensity of effort required.
As for the attribute concerning pollution for each mode, it corresponds to the average risk of the population of the urban area if 50%, 75% or 90% of the population uses this mode of transport on a regular basis. The 50% penetration level reflects approximatively the current situation observed in Grenoble (when gathering all the alternatives to the car, see SMMAG (2021)). Percentages of sustainable transport modes ranging from 75% to 90% can be observed in other European cities (Noussan, 2019) where either the public transport network is very dense (Paris (82%)) or the cycling infrastructure is particularly developed (Amsterdam or Copenhagen (65%)).

To ensure that these health attributes were well-understood by our participants, we used smileys. We were actually inspired by a number of health studies (Johnson et al., 2014; Bolt et al., 2019) that explained in their DCEs treatment programs the health risks using pictograms and illustrations. We present in appendices C.2 and C.3 the way we use smileys to explain the attributes in our DCE. To the best of our knowledge, no previous studies about transportation choices have used smileys as pictograms to explain attributes.

The participant faces nine hypothetical choice situations. For the first two choices (i.e. step 1 of the DCE), we present only two attributes (cost and time) to describe the transportation alternatives. In the following seven choices (i.e. step 2 of the DCE) we introduce the two attributes related to health (see appendix C.4 for a screenshot of an example of a choice exercise from step 2 of the DCE).[5]

To define the reference levels of the time and cost attributes that describe the mode usually used by the participant to do his regular trip (his status quo), we use origin-destination matrices. Knowing the distance between the centres of two zones, it is possible to find the reference times for trips made by car or by bicycle, using the API of Google Map and Odomatrix (Hilal, 2010), and the reference times for trips by public transport with the outputs of the assignment stage of the multi-modal model of the Grenoble conurbation. For health-related attributes, benchmarks are defined as absolute risks of developing cardiovascular disease. We have set the absolute risk for the car at 30% (Inserm, 2018). The levels for all attributes are set as described in Table 3.1.

In order to build our experimental design, we used the software NGENE (Choice-

[5]Step 1 was designed to familiarize the respondent to the choices he will have to make using a limited number of attributes (cost and time only). The choices resulting from this step will therefore not be considered in our main analysis.

Metrics, 2012). We created an efficient design that can take into account the information we have on priors and the reference alternative. We evaluated the efficiency of the design thanks to the D-error. We obtained D-errors ranging between 0.02 and 0.1, which indicates a high statistical efficiency (covariances of the parameter estimates being low).

Finally, no dominant alternatives were found in any of the choice situations generated by the designs after careful manual checks.[6]

3.2.2 Data

The data was collected between June and September 2019. 792 participants were recruited for this survey.[7] To be illegible, the respondent must live in one of the 49 municipalities of the Grenoble metropolitan area, be 18 years old or more, have a driving licence and at least one car in her household.

The descriptive statistics of the sample show that 49% of respondents are men, average age is 52 years old. 32% and 36% of respondents were presented the framing regarding the public health attributes where 75% and 90% of the population uses each mode of transport on a regular basis respectively, the 50% framing was presented to the remaining respondents. More than two-thirds of the reference trips are for commuting to work. 58% of the status quo are made by car, 26% by public transport and 16% by bicycle. The corresponding figures are 52%, 11% and 5% in the Grenoble area based on the 2020 mobility survey.[8]

[6]The manual checks were carried out once the different scenarios had been created independently by the authors of the chapter.

[7]We consider here the participants who have a reference trip above three kilometers. 208 additional individuals answered this survey but they have a reference trip below 3 km and are thus not included in the reported analyses.

[8]page 8: Figures for other cities of similar size are provided here: https://smmag.fr/wp-content/uploads/2021/12/Lettre_dinformations-EMC2.pdf

Table 3.1: Attributes and levels

Attribute	Mode	Definition	Levels
Time	Car	Time to get the car, time spent in the car, searching for a parking spot and to reach the final destination	tempsvoit × [0.8/ **1**/ 1.3] + 3 min
	Public transport	Time to go to the station and waiting time, time in the public transport and to reach the final destination	tempsPT × [0.7/ **1**/ 1.2] min
	Bicycle	Time spent on the bicycle to get from departure to the final destination	tempsbike × [0.7/ **1**/ 1.2] + 3 min
Cost	Car	Cost of fuel (one way)	coutvoit × [**1**/ 1.5/ 2] €
	Public transport	Cost of a public transport ticket	[0/ **0.50**/ 1.50] €
Pollution (Public health)	Car	Average risk of developing a cardiovascular disease for a person in the Grenoble urban area considering that [50/75/90]% of the population adopt this mode of transport	30%
	Public transport		[27/**28**/29]%
	Bicycle		[25/**26**/27]%
Physical activity (Individual health)	Car	Individual risk of developing a cardiovascular disease	30%
	Public transport		[24/**26**/28]%
	Bicycle		[15/**20**/25]%

Notes: In the level column, figures in bold refer to the "status-quo" levels.
coutvoit = (0.12*(km-3)) rounded up to the nearest 0.5.
tempsmode: duration found on google maps or odomatrix.

3.3 Model framework

3.3.1 Embedding risk in the Discrete Choice Model (DCM) framework

The main objective of this work is to introduce health dimensions in the process choice of a mode of transport, with a distinction between individual health related to (a lack of) physical activity (hereafter noted *phys* in the equations) and collective health related to pollution (noted *poll*). For each alternative j (j =car, public transport, bike), we therefore introduce two prospect sets $X_j^h := (E_{1,h} : M_h^{E_{1,h}}, E_{2,h} : M_h^{E_{2,h}})$ with h the two health dimensions ($h \in H = (poll, phys)$) and two mutually exclusive outcomes.

Each event E_h ($E_h \in E_h = (E_{1,h}, E_{2,h})$) results in a health outcome. The first outcome corresponds to cardiovascular morbidity ($M_h^{E_{1,h}} = 1$) and it occurs with probability $p_j^{E_{1,h}} = p_{j,h}$ for each alternative j. If we are interested in the impact of mode choice on physical activity ($h = phys$), then morbidity directly affects the person who makes the choice, who is sick or not. If we consider the impact of mode choice on pollution ($h = poll$), then morbidity affects an average individual in the population. The second outcome corresponds to no cardiovascular morbidity ($M_h^{E_{2,h}} = 0$), with probability $p_j^{E_{2,h}} = 1 - p_{j,h}$.

The decision maker n ($n = 1, \ldots, N$) chooses the alternative that maximises her attribute additive utility function:

$$U_{n,j} = \sum_{E_{poll} \in E_{poll}} W(p_j^{E_{poll}}) \sum_{E_{phys} \in E_{phys}} W(p_j^{E_{phys}}) \tilde{V}_{n,j}(\mathbf{x_n}, \tilde{\mathbf{y}}_{\mathbf{n,j}} | E_{poll}, E_{phys}, \tilde{\boldsymbol{\beta}}_j) + \epsilon_{n,j}, \tag{3.1}$$

$W(.)$ is known as a "weighting function" and will be defined later. $\tilde{V}_{n,j}$ is the deterministic part of the utility function, which depends on a vector of individual variables $\mathbf{x_n}$ and on a vector of alternative-specific variables $\tilde{\mathbf{y}}_{\mathbf{n,j}}$. $\epsilon_{n,j}$ are idiosyncratic error terms. In our application, they will be either independently and identically distributed across individuals and alternatives according to a type I Extreme Value distribution to obtain a multinomial logit model (MNL) or Generalized Extrem Value distributed to obtain a mixed logit model (ML). $\tilde{\boldsymbol{\beta}}_j$ is a vector of unknown parameters to be estimated. The framework of these Discrete Choice Models (DCM) is standard and extensively defined in Train (2009, see Chapters 3 and 6). Discrete choice models are based on the idea that each individual chooses the alternative that provides the greatest utility. From the observation of individuals' choices in the DCE and the knowledge of the variables involved in their choice ($\mathbf{x_n}$,$\tilde{\mathbf{y}}_{\mathbf{n,j}}$,$p_{j,poll}$,$p_{j,phys}$), it is possible to estimate the parameters of the model ($\tilde{\boldsymbol{\beta}}$).

Considering the econometric model, the originality of our work is to introduce a risky dimension in this DCM framework, in the line of De Palma et al. (2008)

and Bouscasse and de Lapparent (2020). For the car alternative, the probability $p_{car,h}$ is constant (0.3). For the other alternatives (j = public transport, bike), it varies accross the choice sets but is always lower than 0.3. We consider that the survey's respondents process the probabilities as the difference between the constant morbidity probability for car and the morbidity probability for the alternative j : $p_{car,h} - p_{j,h}, \forall j = \text{car}, \text{public transport}, \text{bike}$. This formulation is related to the reference dependence theory of Tversky and Kahneman (1991).

We are aware that in the work of Tversky and Kahneman it is the outcome which is reference-dependent. In our setting, the outcome M_h is a dichotomous variable ($M_h = 1$ if morbidity occurs and $M_h = 0$ otherwise). The relevant information for the individuals is therefore the probability and how it varies across the alternatives. The car is chosen as the reference alternative as it is the most used transport mode in the population and in the survey's sample.

The probability weighting function is therefore defined as

$$W(p_{j,h}) = \begin{cases} w(p_{car,h} - p_{j,h}) & , \text{ if } M_h = 1 \\ 1 - w(p_{car,h} - p_{j,h}) & , \text{ if } M_h = 0 \end{cases} \tag{3.2}$$

A second contribution concerning the risky component of the utility function is that we analyse how these probabilities are perceived by the individuals, by defining $W(.)$ as a power function (Yaari, 1987; Bouscasse and de Lapparent, 2020):

$$w(p_{h,car} - p_{h,j}|\delta_h, \beta_h) = \beta_h (p_{h,car} - p_{h,j})^{\delta_h} \tag{3.3}$$

with β_h a parameter to estimate, which expresses how the perceived probabilities impact the utility.

Note that when $\delta_h > 1$, the individual overestimates the probabilities difference $p_{car,h} - p_{j,h}$ (see Figure 3.1, red line). She is said to be optimistic. When $\delta_h = 1$, the difference in probabilities is well perceived, with no bias (Figure 3.1, grey line). When $0 < \delta_h < 1$, the individual underestimates the probabilities difference $p_{car,h} - p_{j,h}$ (Figure 3.1, purple line). She is said to be pessimistic. Simplicity of such a formulation comes at a cost: individuals are always pessimistic or optimistic whatever is the proposed probability $p_{j,h}$.

Third, in order to analyse the perception of health risks and their impact on behaviour, a framing effect is introduced. It is translated into a vector ($\boldsymbol{A} = (A_{50}, A_{75}, A_{90})$) reflecting the proportion of the population which adopts an alternative mode to the car (50%, 75% and 90%; see Section 3.2.2). We test how this framing influences the probability perception of the pollution dimension. From a formal point of view, the coefficients β_{poll} and δ_{poll} are decomposed between a baseline part which corresponds to the 50% framing (β_{poll50} and δ_{poll50}) and additional

effects related to the 75% and 90% framing (β_{poll75}, β_{poll90}, δ_{poll75} and δ_{poll90}), with ($\boldsymbol{\beta}_{poll}^T = (\beta_{poll50}, \beta_{poll75}, \beta_{poll90})$ and $\boldsymbol{\delta}_{poll}^T = (\delta_{poll50}, \delta_{poll75}, \delta_{poll90})$).

For pollution, we therefore refine the definition of w as:

$$w(p_{poll,car} - p_{poll,j}|\boldsymbol{\beta}_{poll}, \boldsymbol{\delta}_{poll}) = (\beta_{poll50} + \beta_{poll75}A_{75} + \beta_{poll90}A_{90}) \\ (p_{poll,car} - p_{poll,j})^{\delta_{poll50}+\delta_{poll75}A_{75}+\delta_{poll90}A_{90}} \tag{3.4}$$

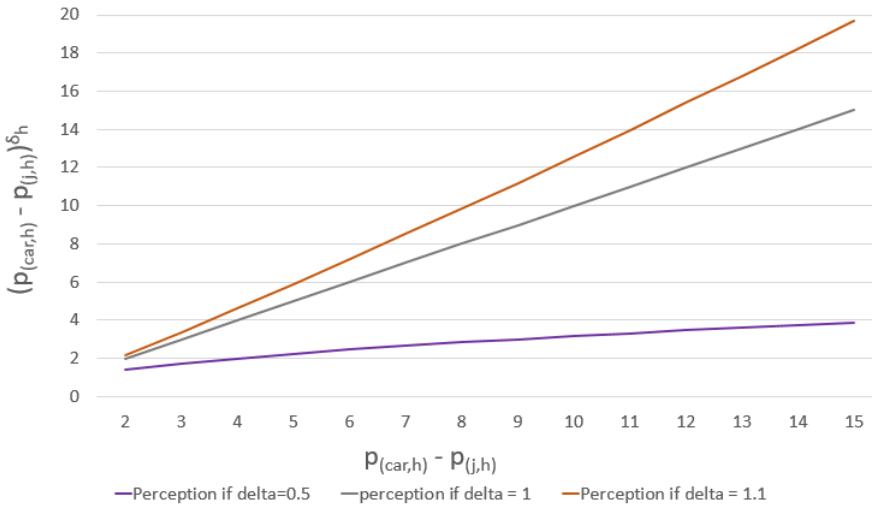

Figure 3.1: Risk perception

Notes: On the x-axis is represented the real risk reduction and on the y-axis is represented the perceived risk reduction. When $\delta_h = 1$ (grey line), risk reduction is well perceived: e.g., to a risk reduction of 5 points corresponds a perception of reduction of 5 points. When $\delta_h > 1$ (red line), risk reduction is overestimated: e.g., to a risk reduction of 5 points corresponds a perception of reduction of 5.9 points. When $\delta_h < 1$ (purple line), risk reduction is underestimated: e.g., to a risk reduction of 5 points corresponds a perception of reduction of 2.2 points. Note that in this case, the perception of reduction varies little with the actual reduction

3.3.2 Estimation strategy and outputs

Since the outcomes of the events only affect health and that the health attributes are independent, the other alternative-specific variables remain unchanged, such that Equation (3.1) is equivalent to the following attribute additive utility function:

$$U_{n,j} = w(p_{j,poll}|\boldsymbol{\beta}_{poll}, \delta_{poll}) + w(p_{j,phys}|\beta_{phys}, \delta_{phys}) + V_{n,j}(\mathbf{x_n}, \mathbf{y_{n,j}}|\boldsymbol{\beta}) + \epsilon_{n,j}, \tag{3.5}$$

where $\mathbf{y_{n,j}}$ is a vector of alternative-specific variables except the health attributes ($\tilde{\mathbf{y}}_{\mathbf{n,j}}^T = (p_j^{phys}, p_j^{poll}, \mathbf{y_{n,j}^T})$), $\boldsymbol{\beta}_j$ is a vector of unknown parameters that excludes those associated to health ($\tilde{\boldsymbol{\beta}}_j^T = (\beta_{poll}, \beta_{phys}, \boldsymbol{\beta}_j^T)$) and $V_{n,j}$ is the deterministic part of the utility function that define additive functional relations between $\mathbf{x_n}, \mathbf{y_{n,j}}$ and $\boldsymbol{\beta}_j$.

More precisely, the vector $y_{n,j}^T = (\text{Cost}_{n,j}, \text{Time}_{n,j}, \text{A}_n)$ is composed for each alternative of travel cost, travel time and framing effect as presented in the DCE for alter-

native j and individual n. The vector $\mathbf{x_n}^T = (age_n, gender_n, status_{PT,n}, status_{cycling,n})$ is composed of the individual characteristics (see Table 3.2 for a definition of these variables). The vector $\boldsymbol{\beta}_j^T = (\text{ASC}_j, \beta_{j,\text{Time}}, \beta_{\text{Cost}}, \beta_{\text{A}}, \beta_{\text{age}}, \beta_{\text{gender}}, \beta_{\text{status}_{PT}}, \beta_{\text{status}_{cycling}})$ contains the Alternative-Specific Constant (ASC), the parameters associated with travel time, travel cost and the framing effect, as well as the parameters associated with the individual variables.

As mentioned above, we adopt two modeling structures: a MNL model and a ML model, with which we intend to explore heterogeneity in the behaviours of respondents regarding the two health attributes. The parameters associated with health (β_{phys} and $\boldsymbol{\beta}_{poll}$) are supposed to follow a normal distribution. The other coefficients remain constant. We solve the ML model through simulations with 10,000 Monte Carlo draws.

Considering the notations introduced, Equation 3.5 can be re-written

$\forall j \in \{\text{car, public transport, cycling}\}$ in the following way:

$$\begin{aligned} U_{nj} = \quad & ASC_j + \beta_{j,Time} Time_{n,j} + \beta_{Cost} Cost_{n,j} + \beta_A A_n \\ & + (\beta_{poll50} + \beta_{poll75} A_{75} + \beta_{poll90} A_{90})(p_{poll,car} - p_{poll,j})^{\delta_{poll50} + \delta_{poll75} A_{75} + \delta_{poll90} A_{90}} \\ & + \beta_{phys}(p_{phys,car} - p_{phys,j})^{\delta_{phys}} \\ & + \beta_{age} age_n + \beta_{gender} gender_n + \beta_{status_{PT}} status_{PT,n} + \beta_{status_{cycling}} status_{cycling,n} \\ & + \epsilon_{n,j} \end{aligned} \tag{3.6}$$

As outputs of these models, we define the willingness to pay for travel time (i.e. Value of Time, VoT) for each mode of transport, willingness to pay to gain percentage point of risk reduction[9] in individual health risk related to physical activity (WTP_{phys}) and willingness to pay to gain percentage points of risk reduction in health risk of the population related to air pollution, for each framing (WTP_{poll50}, WTP_{poll75} and WTP_{poll90}). We recall that WTP is the variation of the cost attribute (β_{cost}) that an individual would accept to maintain the same level of utility when there is a variation in another attribute (e.g. Time attribute in the case of calculating the VoT). In the case of ML models, the coefficient of cost β_{cost} remains fixed. The calculated WTP for a reduction of risk are normally distributed, following the distribution of the random health coefficients (β_{phys} and $\boldsymbol{\beta}_{poll}$).

We calculate the WTP as follow:[10]

[9] E.g. reduction from 30% to 20% of developing a cardiovascular disease.

[10] "In calculating a measure of WTP, it is important that both attributes to be used in the calculation are found to be statistically significant, otherwise no meaningful WTP measure can be established." (Hensher et al., 2005, p. 359)

$$
\begin{aligned}
VOT_j &= -\frac{\beta_{j,Time,j} \times 60}{\beta_{cost}} \\
WTP_{j,phys} &= -\frac{\delta_{phys}\beta_{phys} \times (p_{phys,car} - p_{phys,j})^{\delta_{phys}}}{\beta_{cost}} \\
WTP_{j,poll50} &= -\frac{\delta_{poll50}\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{\delta_{poll50}-1}}{\beta_{cost}} \\
WTP_{j,poll75} &= -\frac{(\delta_{poll50} + \delta_{poll75})\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{(\delta_{poll50}+\delta_{poll75})-1}}{\beta_{cost}} \\
WTP_{j,poll90} &= -\frac{(\delta_{poll50} + \delta_{poll90})\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{(\delta_{poll50}+\delta_{poll90})-1}}{\beta_{cost}}
\end{aligned}
\tag{3.7}
$$

Table 3.2: Descriptive statistics

Label	**Definition**	**Proportion (%)**
Sample = 792 participants		
Individual variables		
Age	Age (in years)	51.82 (12.44)
Gender	Gender (=1 if man; =0 if woman)	48.99
$Status_{Car}$	Usual car user to go to work (=1 if yes; =0 otherwise)	57.58
$Status_{PT}$	Usual public transport user to go to work (=1 if yes; =0 otherwise)	26.01
$Status_{Bicycle}$	Usual Bicycle user to go to work (=1 if yes; =0 otherwise)	16.41
Sample = 792 participants		
Framing of the risk information		
75% of population	75% of the population adopt the same mode (=1 if yes; =0 otherwise)	31.94
90% of population	90% of the population adopt the same mode (=1 if yes; =0 otherwise)	35.61
Sample = 5,544 observations		
Alternative specific variables		**Mean**
$Cost_{Car}$	Travel cost by car (in euros)	1.32 (0.7)
$Cost_{PT}$	Travel cost by public transport (in euros)	0.62 (0.54)
$Time_{Car}$	Travel time by car (in minutes)	23.28 (8.06)
$Time_{PT}$	Travel time by public transport (in minutes)	33.59 (13.2)
$Time_{Bicycle}$	Travel time by bicycle (in minutes)	28.4 (14.37)

Notes: Standard deviation are between parentheses; PT stands for Public Transport

3.3.3 Tested hypotheses with the model

In order to simplify the notations, hereinafter, we will use the notation $\boldsymbol{\beta}_{\boldsymbol{poll}}^{\boldsymbol{Total}} = (\beta_{poll50}, \beta_{poll50} + \beta_{poll75}, \beta_{poll50} + \beta_{poll90})^T$. Similarly, we will use the notation $\boldsymbol{\delta}_{\boldsymbol{poll}}^{\boldsymbol{Total}} = (\delta_{poll50}, \delta_{poll50} + \delta_{poll75}, \delta_{poll50} + \delta_{poll90})^T$.

The following hypotheses are tested:

- H1: Health benefits of the used mode of transport impact mode choice.

  ➜ $\boldsymbol{\beta}_{\boldsymbol{poll}}^{\boldsymbol{Total}}$ and β_{phys} are significantly different from zero and strictly positive.

- H1bis: Pollution effect on health has a smaller impact than physical activity on mode choice.

  ➜ $\boldsymbol{\beta}_{\boldsymbol{poll}}^{\boldsymbol{Total}} < \beta_{phys}$.

- H2: There is an heterogeneity in the perception of individuals concerning the health impact on mode choice. One may anticipate that depending on his socio-demographic characteristics and status quo, an individual will more or less take into account the health related information presented in this study.

  ➜ std($\boldsymbol{\beta}_{\boldsymbol{poll}}^{\boldsymbol{Total}}$) and std($\beta_{phys}$) are significantly different from zero.

- H3: Probabilities are misperceived, with an underestimation of the probability differences. Indeed, according to Tversky and Kahneman (1991), decision-makers tend to underestimate gains and overestimate losses. In the way the DCE is designed, individuals should consider a gain in the probability of morbidity occurrence. One noticeable departure from Tversky and Kahneman (1991) is the fact that we expressed gains in terms of percentage points instead of amounts.

  ➜ $0 < \boldsymbol{\delta}_{\boldsymbol{poll}}^{\boldsymbol{Total}} < 1$ and $0 < \delta_{phys} < 1$.

- Framing effect (FE): The introduction of different share of population adopting the alternative mode of transport allows us to explore two different mechanisms. We may either face a conformity effect which would imply that the higher the share of population who used alternative modes of transport, the higher the impact of pollution related health risk on mode choice or a free rider mechanism where a high share of the population already adopting alternative transport modes reduces the probability that the individual decide to do the same. The framing effect is therefore *a priori* ambiguous and we do not make any assumptions about which effect (conformity or free-riding) is dominant.

3.4 Results and discussion

3.4.1 Estimation results

Table 3.3 presents the results of the multinomial (MNL) and mixed logit (ML) regressions.[11] For the interpretations of the two models, we choose the car as a reference mode which means that we normalise the *ASC* of the car to zero.

The first result is that information about the individual and public health risks significantly influences the preferences of the participants (*H1 confirmed*, see Table 3.4). More precisely, information about individual cardiovascular reduction risk induced by physical activity related to alternatives to the car has a significant and positive effect. Results are similar with respect to collective health risk reduction related to pollution. This means that the higher the risk reduction for cardiovascular disease is, the greater the likelihood that an alternative mode of transport to the car will be chosen.

Regarding hypothesis *H1bis*, the information that has the most effect between individual and collective health information depends on the share of the population adopting the alternative mode (see Table 3.4). More precisely, while the impact of individual health benefits does not differ from population health benefits when either 50% or 75% of the population also adopt the alternative transport mode, the individuals who were presented with a 90% framing are more likely to declare they would either bike or use public transport. Put differently, the information related to the general population reduction risk predominates over the individual reduction risk to develop a cardiovascular disease when an extremely large share of the population adopts an alternative mode to the car. This latter result tends to indicate that in our specific context, the conformity mechanism is at play rather than free riding (FE). Until now, information campaigns have focused on environmental issues (reduction of pollution or greenhouse gases). However, given the modal shares observed in Grenoble, our results show that pointing out the individual health benefits of adopting alternative modes can also be a lever for encouraging citizens to reduce car use.

In addition, we find that standard deviations of the normally randomized health coefficients are not significantly different from zero. In other words, no heterogeneity in behaviours between respondents are detected with respect to the different health attributes introduced in the choice exercises (*H2 not confirmed*, see Table 3.3). One could expect people with higher environmental or health preferences to be more responsive to the information provided. Unfortunately, we did not collect this type of information in the survey.

Risk perception's results show that respondents appear to largely under evalu-

[11] These results were obtained using PythonBiogeme (Bierlaire, 2016).

ate the risk reduction presented, as δ_h parameters are close to zero (see Table 3.3) and statistically different from one (p-value<0.001) for both health attributes and whatever the framing (*H3 confirmed*). These results suggest that there is a large fixed effect of the information about the health impact of car use but that marginal effects are almost nonexistent when the risk reduction increases. Therefore, it is important to provide quantitative information on the expected risk reduction in future information campaigns encouraging the adoption of alternative modes of transport to the car to show the extent of the reduction and the credibility of the reduction. However, it is not necessary for governments to differentiate precisely the expected reduction according to the health characteristics of its population.

In regards to the effects of the remaining attributes. We notice that, whatever the specification of the model, the coefficients for the cost attribute are significantly different from zero at a 99% confidence level. As expected, cost coefficients are negative meaning that a higher cost impacts negatively the utility of the participant and discourages the use of the mode of transport.

Concerning the time attribute, alternative specific coefficients are considered. The duration of the trip has a significant and negative effect on the utility. This effect appears to influence differently the choice of the proposed alternatives. The results show that people perceive less negatively the time spent in the car compared to the public transport, and even less negatively compared to the bicycle (see also next Section for an interpretation of the VoT).

Finally, for all models, the reference mode of the participant (i.e. the status quo) has a significant effect on the choice. Given that coefficients for the status quo ($STATUS_{PT}$, $STATUS_{BICYCLE}$) are positive, participants who do not have the car as status quo prefer to choose an alternative mode to the car.

Table 3.3: Estimation results

Variables	MNL model	ML model	
		Mean	SD
$ASC_{Bicycle}$	-53.4 (7.34)***	-48.5 (6.39)***	
ASC_{PT}	-52.5 (7.23)***	-47.7 (6.27)***	
ASC_{Car}			
β_{cost}	-0.64 (0.06)***		-0.64 (0.06)***
$\beta_{Bicycle,Time}$	-0.08 (0.003)***	-0.08 (0.003)***	
$\beta_{PT,Time}$	-0.07 (0.004)***	-0.07 (0.004)***	
$\beta_{Car,Time}$	-0.04 (0.006)***	-0.04 (0.006)***	
β_{phys}	30.1 (3.76)***	28 (3.49)***	0.06 (0.1)
β_{poll50}	23 (4.85)***	20.3 (3.94)***	-0.001 (0.07)
β_{poll75}	15.5 (8.22)*	13.8 (6.05)**	0.003 (0.04)
β_{poll90}	31.3 (9.14)***	29.1 (3.53)***	-0.09 (0.14)
δ_{phys}	0.02 (0.001)***	0.02 (0.001)***	
δ_{poll50}	0.02 (0.003)***	0.03 (0.003)***	
δ_{poll75}	-0.007 (0.004)*	-0.008 (0.004)*	
δ_{poll90}	-0.007 (0.003)**	-0.009 (0.003)***	
A_{75}	-15.2 (8.27)*	-13.6 (6.09)**	
A_{90}	-31.4 (9.19)***	-29.3 (3.53)***	
Gender	0.073 (0.07)	0.07 (0.07)	
Age	-0.05 (0.02)**	-0.05 (0.02)**	
Age^2	0.0003 (0.0002)	0.0003 (0.0002)	
$Status_{Car}$			
$Status_{PT}$	1.81 (0.11)***	1.81 (0.11)***	
$Status_{Bicycle}$	2.65 (0.18)***	2.65 (0.18)***	
$L(\hat{\beta})$	-4821.188	-4821.252	
$\bar{\rho^2}$	0.205	0.205	
Observations	5,544	5,544	

Notes: Standard errors are in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$
MNL model: Multinomial logit model.
ML model: Mixed logit model. Estimated using 10,000 Monte Carlo draws.
SD: standard deviation of the normally randomized health coefficient.
PT stands for Public Transport.

Table 3.4: Test of statistical difference between health coefficients (β)

	β_{poll50}	$\beta_{poll50} + \beta_{poll75}$	$\beta_{poll50} + \beta_{poll90}$	β_{phys}
Value	23	38.5	54.3	30.1
95% CI	[13.49;32.51]	[26.15;50.85]	[45.42;63.18]	[22.73;37.47]
β_{poll50}	SP (***)	SD (*)	SD (***)	NSD
$\beta_{poll50} + \beta_{poll75}$		SP (***)	NSD	NSD
$\beta_{poll50} + \beta_{poll90}$			SP (***)	SD (**)
β_{phys}				SP (***)

Notes: CI means Confidence Interval; SP means Significantly Positive; SD means Significantly Different. NSD means Non Significantly Different. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Reading note: H1 : The diagonal elements show that the first hypothesis is satisfied: all health parameters are positively significant. FE : The pink off-diagonal elements show that there is a positive framing effect, with a conformity mechanism which dominates the free-riding mechanism, when comparing the 75% and 90% framing to the 50% framing. H1bis : The green off-diagonal elements show that hypothesis H1bis is not confirmed. Pollution effect on health does not have a significant smaller impact than physical activity on mode choice. And it has even a higher impact with the 90% framing.

3.4.2 Economic outputs: Willingness to pay (WTP) and Value of time (VoT)

Tables 3.5 and 3.6 show the mean WTP and confidence intervals for the MNL and ML models respectively. Table 3.7 shows the VoT and confidence intervals derived from the choice models.

Starting with the WTP, our results show that for a two percentage points individual risk reduction of developing a cardiovascular disease, individuals are ready to pay 0.85 euro per trip made by public transport. This WTP hardly varies with risk reduction (see Figure 3.2). Similar WTP are obtained for cardiovascular disease's risk reduction in the entire population when the respondent is told that 50% of the population adopt the mode of transport. This WTP significantly increases when the share of population adopting the mode of transport increases. More precisely, these WTP are equal to 0.82, 0.93 and 1.27€ per trip made in public transport for one point reduction in risk when 50%, 75% and 90% of the population adopt the mode of transport respectively. Very similar results are obtained for a risk reduction corresponding to the use of a bicycle instead of a car. The obtained WTP in the different framing are not statistically different from one another even if this value becomes larger and larger when the share of individuals adopting the alternative mode of transport increases. We are not able in this study to disentangle the conformity mechanism from the willingness to finance for infrastructures allowing most of the population to reduce the use of the car.

It is possible to analyse these results further from the point of view of policy recommendations. Bergerot et al. (2021) quantified the external costs of the car (road wear and tear, time lost in traffic jams, CO_2 emissions, air pollution, noise and accidents) at 0.165 € per kilometer. Assuming an average distance of 8.2 kilometers (observed in our sample), the order of magnitude of the external costs of car use for society (1.32 € per trip) is similar to the individual value of a trip with alternative modes to the car in order to improve health, whether we consider i) the pollution component with a 90% framing (1.27 to 1.30 €) or ii) the physical activity component added to the pollution component with a 50% framing (1.53 to 1.71 €). This concordance between private costs, the reduction of which is an individual objective, and external (societal) costs, the reduction of which is an objective of the public authority, thus also makes individual ambitions and public policies coincide. This means that by using health as a lever and justification for public policy, it is possible to achieve societal objectives with means that are acceptable to public policy. Even as the acceptability of public policies to restrict automobile traffic is an important issue (cf. Chapter 1), the recent covid pandemic has shown that the public is willing to make significant concessions when it comes to health. Moreover, this approach is consistent with the idea that self-determined motivations (Deci and

Ryan, 1995) are essential for inducing intention of behavioural change (cf. Chapter 2).

When turning to the Value of time, we obtain for car a VoT equal to 4.13 €/hour. These values are close to the low range of French guideline values ($VoT_{car} = 5.5$ €/hour in (Quinet et al., 2014)) and literature (Wardman et al., 2012). The public transport VoT is equal to 6.91 €/hour, which is consistent with the French values of Wardman et al. (2012)'s meta-analysis where they had a $VoT_{PublicTransport} = 5.17$ €/hour. There are still very few studies on the value of time of active modes.

For cycling, our VoT is relatively lower than the range of the values provided in Börjesson and Eliasson (2012). Our $VoT_{Bicycle}$ is equal to 7.31 €/hour compared to the $VoT_{Bicycle}$ of Börjesson and Eliasson (2012) that ranges between 11 and 16 €/hour.

A higher VoT for the bicycle and public transport compared to the car may result from the fact that 58% of the sample are usual car users. So, asking car users to change their modal choice requires them a costly effort, which reflects in VoT. This intuition must be confirmed by analysing the heterogeneity of VoT by type of user.

Table 3.5: Willingness to pay (in €) - Multinomial Logit model

Risk reduction (in points)	Pollution 50%	Pollution 75%	Pollution 90%	Physical activity
Public transport				
1	0.80 [0.47;1.08]	0.93 [0.60;1.18]	1.27 [0.90;1.61]	-
2	0.81 [0.47;1.09]	0.94 [0.61;1.19]	1.28 [0.91;1.63]	0.85† [0.67;1.10]
3	0.82 [0.48;1.10]	0.95 [0.62;1.20]	1.29 [0.91;1.64]	-
4	-	-	-	0.86 [0.68;1.11]
6	-	-	-	0.87 [0.68;1.12]
Bicycle				
3	0.82 [0.48;1.10]	0.95 [0.62;1.20]	1.29 [0.91;1.65]	-
4	0.82 [0.48;1.11]	0.95 [0.62;1.21]	1.29 [0.92;1.64]	-
5	0.83 [0.49;1.12]	0.96 [0.62;1.21]	1.30 [0.92;1.65]	0.87 [0.68;1.12]
10	-	-	-	0.88 [0.69;1.13]
15	-	-	-	0.88 [0.69;1.14]

Notes:

95% confidence intervals between brackets

For each mode of transport, the WTP are presented only for the risk reduction proposed in the DCE; see Table 3.1. Given our model (see Equation 3.6), the WTP only depend on the level of risk reduction and not on the mode of transport.

† For a two percentage points individual risk reduction of developing a cardiovascular disease (going from 30% to 28%), individuals are ready to pay 0.85 euro per trip made by public transport.

‡ For a four percentage points population risk reduction of developing a cardiovascular disease (going from 30% to 26%), individuals are ready to pay 0.82 euro per trip made by bicycle when 50% of the population also adopt this transport mode.

Table 3.6: Willingness to pay (in €) - Mixed Logit model - mean values

Risk reduction (in points)	**Pollution** 50%	75%	90%	**Physical activity**
Public transport				
1	0.79 [0.48;1.09]	0.93 [0.65;1.15]	1.27 [0.95;1.55]	-
2	0.81 [0.49;1.12]	0.94 [0.65;1.17]	1.28 [0.96;1.57]	0.86† [0.67;1.03]
3	0.82 [0.49;1.13]	0.95 [0.66;1.18]	1.29 [0.96;1.58]	-
4	-	-	-	0.87 [0.68;1.05]
6	-	-	-	0.87 [0.68;1.06]
Bicycle				
3	0.82 [0.49;1.13]	0.95 [0.66;1.18]	1.29 [0.96;1.58]	-
4	0.82 [0.50;1.14]	0.95 [0.66;1.18]	1.29 [0.97;1.59]	-
5	0.83 [0.50;1.15]	0.96 [0.67;1.19]	1.30 [0.97;1.60]	0.87 [0.69;1.06]
10	-	-	-	0.88 [0.69;1.07]
15	-	-	-	0.89 [0.70;1.08]

Notes:

95% confidence intervals between brackets

For each mode of transport, the WTP are presented only for the risk reduction proposed in the DCE; see Table 3.1. Given our model (see Equation **??**), the WTP only depend on the level of risk reduction and not on the mode of transport.

† For a two percentage points individual risk reduction of developing a cardiovascular disease (going from 30% to 28%), individuals are ready to pay 0.86 euro per trip made by public transport.

‡ For a four percentage points population risk reduction of developing a cardiovascular disease (going from 30% to 26%), individuals are ready to pay 0.83 euro per trip made by bicycle when 50% of the population also adopt this transport mode.

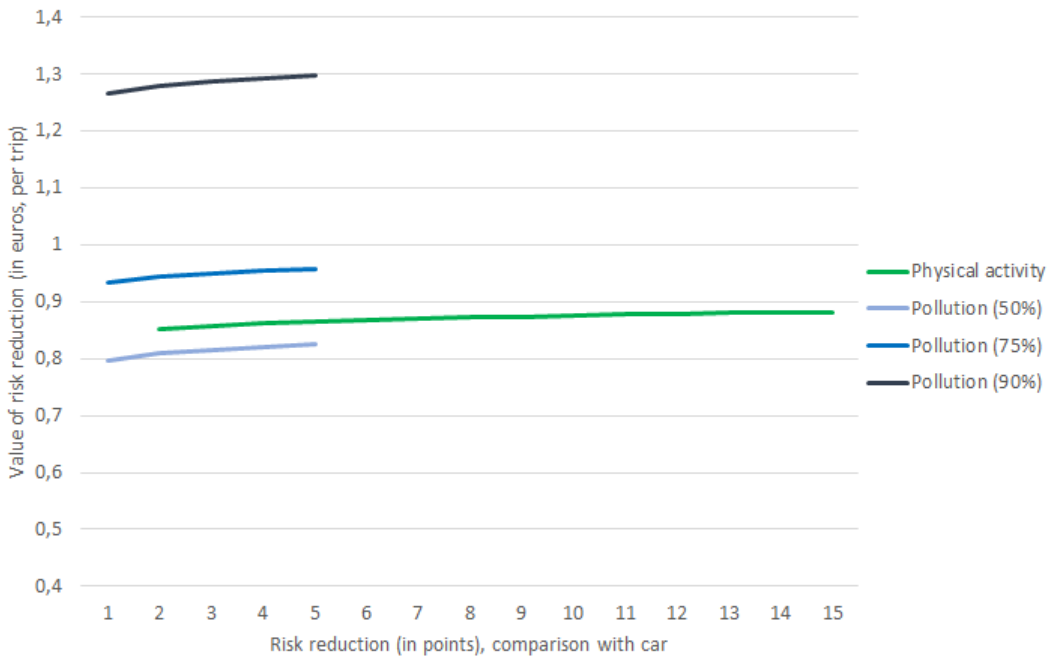

Figure 3.2: Willingness to pay to reduce the risk of developing a cardiovascular disease

Table 3.7: Value of time (VOT; in €/hour)

	MNL model	ML model
Car	4.13 [2.69;5.86]	4.13 [2.80;5.64]
Public Transport	6.91 [5.63;8.11]	6.91 [5.84;8.26]
Bicycle	7.31 [6.09;8.58]	7.31 [6.16;8.59]

Notes:
95% confidence intervals between brackets
MNL model: Multinomial logit model
ML model: Mixed logit model

3.5 Conclusion

In this chapter, we evaluate the extent to which information on the impact of mode choice on public or individual health influences these choices. We implement a Stated Preference survey collecting original data from participants living in the Grenoble metropolitan area. Respondents were presented different scenarios depending on the mode of transport (car, public transport and cycling), travel time, cost and associated cardiovascular risk. To the best of our knowledge, this is the first study that investigates the effect of these kind of information as attributes in a discrete

choice experiment. Further, we consider morbidity (through a risk reduction of developing a cardiovascular disease) instead of mortality and take into account the individual perception of risk reduction probabilities.

Our findings confirm that information on health risks related to air pollution or lack of physical activity have both a significant effect on the preferences of the participants in regards to modal choice. We find positive WTP to reduce individual and public health risks. In particular, we find that the WTP to reduce the individual risk is equal to 0.85€ per trip made by public transport for a risk reduction of 2 percentage points and 0.81€ per trip when considering a similar risk reduction for the population if 50% of the population also adopt this mode of transport. This WTP increases significantly to reach 1.27€ per trip when the share of the population making the same effort (i.e. not using the car) rises to 90%. Similar results are found for cycling. Given that today, in France, the modal share of people using an alternative mode to the car is rather around 50% (in Grenoble Metropolitean Area[12]) or lower, our results indicate that decision makers could play on both the individual and public health impact of modal choices to encourage citizens to reduce car usage.

Regarding some limitations of this work, the results highly depend on the specific case of Grenoble. The metropolis present some particularities that makes it more difficult to generalise the findings. Indeed, Grenoble could be considered a cycling-friendly city since it is very flat and has a well-developed cycling path network called "Chronovélo". It also has a pedestrian city center which encourages walking and the use of public transport. These infrastructure factors certainly influence the answers of the residents of Grenoble in terms of their willingness to modal shift. Other cities may not have such infrastructures. Thus, similar DCEs to the one presented in this work should be tested in other settings. Besides, the use of stated preferences survey has a major limitation being the risk of hypothetical bias. The respondents being in a hypothetical setting could easily over-estimate their real intentions to modal shift which could later result in an intention-behaviour gap. We attempted to control this bias by presenting relatable and personalised scenarios in the DCE. However, combining the stated preference data with revealed preference data would better allow for controlling this bias and verify the existence of the intention-behaviour gap.

[12]This figure comes from the 2019-2020 Mobility survey: https://smmag.fr/wp-content/uploads/2021/12/Lettre_dinformations-EMC2.pdf

Chapter 4

How to go from intentions to actions to orient individuals to adopt socially desirable behaviours? A laboratory experiment

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Abstract

Individual engagement in pro-social and pro-environmental behaviours is essential for the good functioning of the society. They guarantee a continuous access to natural resources and a better population health. But, individuals refrain from these behaviours due to low initial intentions to do the behaviour or, even when having high real intentions, they fail to translate them into action. To encounter these issues, and based on the reasoning process resulting in the formation of intentions and the behaviour, this chapter investigates: if we should influence intentions through cognitive effort (a learning intervention on System 2) or influence the behaviour by harnessing cognitive bias (a default nudge intervention on System 1) in order to efficiently foster pro-social or pro-environmental behaviours? We use a charity game to test the two interventions in an online experiment and compare their effect on the participants' emotions. The results demonstrate a short-term effect of both interventions with higher donations thanks to the default nudge. However, the positive effect of giving on emotions is greater under the learning intervention.

Keywords: intention-behaviour gap, charity game, interventions, emotion

4.1 Introduction

Taking action to tackle the climate emergency and the environmental and health crises requires everyone to become an active player in the solutions to be implemented. Carbon neutrality is required to comply with the climate objective of the Paris Agreement (2015) to limit global warming below 2°C and as close as possible to 1.5°C. The European Union adopted in 2019 with its Green Deal the long-term objective of achieving carbon neutrality by 2050 which is based on a medium-term objective of reducing greenhouse gas emissions by 55% in 2030 compared to 1990. The latest Intergovernmental Panel on Climate Change (IPCC) Working Group III report (2022)[2] highlights the important role that individual actions in food, mobility and residential sectors can play in helping to significantly reduce emissions and achieve carbon neutrality.

Current studies demonstrate a general population willingness to engage in socially and environmentally beneficial behaviours. For instance, in regards to mobility practices, 62% of the French population state that they are ready to switch to less polluting and more active modes (European Commission, 2020). However, beyond these declared intentions real engagement in such practices is still low. Actually, according to the same report, 66% of the population use the car for daily travels compared to significantly lower shares of usual walkers, public transport users and cyclists. Thus, there is a divergence between the declarative surveys and actual behaviour.

Two main reasons could explain the refrain from pro-social or pro-environmental behaviours. First, since intentions are usually defined as the amount of effort one is willing to exert to achieve a goal (Gibbons, 2006), not doing the behaviour could be an expression of a low intention. Second, in certain cases, even if a person expresses high intentions and willingness to do the behaviour, he eventually fails to translate his intention into action. Following the Theory of Planned Behaviour (TPB) (Ajzen, 1991), this discrepancy between intention and behaviour is called the intention-behaviour gap (Sheeran, 2002). Besides, intervention to change behaviour can take one of the two paths according to the Dual-process model of Kahneman (2003): one is to engage System 2 and foster it, the other is to play on System 1's cognitive bias (Hertwig and Grüne-Yanoff, 2017; Grüne-Yanoff and Hertwig, 2016; Grüne-Yanoff, 2018).

In this chapter we aim to design and test two public interventions playing on these two dimensions comparing their efficiency in the encouragement of adopting socially desired behaviours: 1) an intervention reinforcing the intentions and 2) an intervention directly influencing the behaviour in an attempt to reduce an identified

[2]https://www.ipcc.ch/report/ar6/wg3/

gap. In this regards, we postulate that intentions are better influenced by an intervention based on cognitive effort (through a writing task) while behaviours can be modified by harnessing cognitive bias (in particular, status quo bias).

Based on the TPB and nudge literatures, we design two interventions aiming to increase donations in a classic Charity Game (CG) (Eckel and Grossman, 1996). The first intervention consists in asking the subjects to make a cognitive effort to increase their intention of donation. This is similar to the intervention of Zaval et al. (2015) also done with a CG in which they asked their participants to write a text answering the question : How will I be remembered?" before declaring their donation. Consequently, it increased the intention and in turn the donation. For the second intervention, we play on the status quo to increase the donation of the subjects through a default nudge intervention. Previous experimental evidence have demonstrated the efficacy of applying this type of nudge on the donation behaviour which increased the amount of donations (Ghesla et al., 2019).

The goal of both interventions is to encourage the adoption of behaviours that would improve the social well-being. However, it is essential to consider the well-being and emotions of the individual to ensure a better acceptability of the intervention and, therefore, its success. In the literature, few studies evaluate the impact of tested interventions on participants' emotions. Thunström (2019) is one of the few who considered that a menu labeling nudge intervention may generate an emotional cost, also called an "emotional tax."

Thus, we compare the long-term effect of the two interventions on different metrics: intentions, donations, the intention-behaviour gap and emotions.

To preview the results, we find that the intervention on intentions increases the level of intentions temporarily failing to translate into an increase in the level of donation. On the contrary, the intervention on behaviour increases the level of donation but also the level of attrition. Comparing the effect of both interventions on emotions, the one influencing intentions generates more positive emotions than the one directly impacting the behaviour.

The remaining of this chapter is organised as follows. Section 2 lays down the related literature. Section 3 presents the experimental design and procedure. The tested hypotheses are described in section 4. Section 5 includes the results which are discussed in section 6 with some concluding remarks and perspectives.

4.2 Literature review

Understanding the mechanisms and determinants behind the individual adoption of pro-social or pro-environmental behaviours is essential for public authorities to identify efficient levers to encourage such behaviours.

A predominant theory that has been extensively used for this purpose is the TPB (Ajzen, 1991) according to which intentions are the immediate antecedent of the behaviour (Ajzen, 2006).[3]

Public authorities are increasingly designing interventions based on insights from behavioural sciences mainly using nudge interventions (Thaler and Sunstein, 2009). Experimental evidence confirm that nudges are an efficient tool to encourage the adoption of socially desirable behaviours (Andor and Fels, 2018; Butts et al., 2019; Schubert, 2017). Nudges actually harness cognitive biases (eg. myopia, loss aversion, etc.) to influence behaviour. Thus, they are generally applied directly on the behaviour and are less interested in influencing the intentions. We notice that less is known about the nudge's real effect on the intention-behaviour gap since when applying it, intentions are not measured beforehand.

We find few empirical studies using nudges to directly influence intentions and they generally fail in encouraging significantly the adoption of the desired behaviour (Gaudeul and Kaczmarek, 2017; Momsen and Stoerk, 2014). A valid justification of this fail could be the neglect of the process behind the formation of the intentions and the behaviour and how their characteristics fit with those of the intervention. If we actually consider the reasoning process of the individual following the Dual-process model (Kahneman, 2003), we postulate that the behaviour and its originating intentions are the results of the two distinct human reasoning systems: System 1 and System 2 (Terlau and Hirsch, 2015; Torma et al., 2018). We actually suppose that intentions originate from the activation of System 2 since they are the result of a conscious and deliberate thinking process. Whereas the behaviour is a manifestation of a cognitive shortcut with fast and subconscious thinking process activated by System 1. Hence, to create a change in intentions and/or behaviour the tools implemented are likely to be appropriate to the characteristics of their generating systems.

Thus, to influence lastingly the individuals to start and continue adopting the desirable behaviour, it appears to be important not only to act on the behaviour but also on its defining variable, which is here the intentions (Bazart et al., 2019). All these elements beg the question: *Should we apply a cognitive effort to influence intentions or harness cognitive bias to influence the behaviour in order to efficiently foster pro-social or environmental behaviours and maintain them in the long run?* To the best of our knowledge, no previous work has ever compared interventions playing on a behaviour or intention in the same context with an interest in assessing

[3]The intentions are the result of the combination of three elements: 1) *attitude toward the behaviour*, referring to the beliefs that the individual has about the positive or negative consequences of carrying out the behaviour, the 2) *subjective norms*, which reflect the individual's perceived social pressure, and 3) the *perceived behavioural control*, which depends on the individual's beliefs about the degree of control that he has over the behaviour.

their long term effects.

We try to answer this question using a CG (Eckel and Grossman, 1996) to capture pro-social and pro-environmental behaviours (Zaval et al., 2015; Kuhfuss et al., 2022). Indeed, taking action or making effort to prevent global warming may be compared to charitable donation. In both cases, the provision of the public good is so distant in time and space that the effort is closer to an act of charitable giving to an environmental charity than to the provision of a classic public good where cooperation needs to take place.

We test two interventions based on the two distinct reasoning systems: one intervention playing on intention (i.e. a learning intervention through System 2), the other intervention playing on behaviour (i.e. a default nudge intervention through System 1). The aim of the two tested interventions is to encourage the adoption of pro-social and pro-environmental behaviours expressed as a donation to a charity.

Inspired from the recent but growing literature about "boost" interventions, we implement the learning intervention allowing the individual to have a better idea on the implications of his donations as they contribute to defending the causes and actions of the charity (Zaval et al., 2015). The boost intervention "assumes a decision maker whose competences can be improved by enriching his or her repertoire of skills and decision tools and/or by restructuring the environment such that existing skills and tools can be more effectively applied" (Grüne-Yanoff and Hertwig, 2016). An example from this literature is using a boost to help consumers better understand eco-labels in choosing the more sustainable option in the context of tea purchase (Vreeburg, 2020). Thus, boost contribute to communicating transparent and comprehensible information so the person undergoing the intervention is aware of it. The individual's motivation and involvement are actually important conditions for the success of a boost since he is asked to learn and reflect before adopting the behaviour.

The recent meta-analyses of experimental studies done by Saeri et al. (2022) or Noetel et al. (2020) about the most effective interventions to promote donations to charity actually underline the positive impact of interventions that increase the individual awareness of the impact of the donations. In addition, the work of Butts et al. (2019) shows that if the individual knows there is a larger share of beneficiaries from the charity, this would further increase the amount of donation. Besides, when the individual learns more about his intentions, he makes a more informed and mindful decision. Thiermann and Sheate (2020) actually found that there is a positive relationship between mindfulness and the engagement in pro-environmental behaviours. These empirical evidences show the effectiveness of the learning intervention. However, comparisons with other types of interventions like nudges are still limited.

Second, we choose to apply a default option nudge directly on the behaviour to increase the charitable giving. Evidences actually suggest that the default nudge is one of the most powerful nudges (Mertens et al., 2022; Meier et al., 2022; Andor and Fels, 2018). Default set up have been used with success to increase charitable giving in several studies (Ghesla et al., 2019; Zarghamee et al., 2017; Korenok et al., 2014). The default setting in the context of encouraging organ donation presented by Johnson and Goldstein (2003), demonstrated that the fraction of the population that donates organs was significantly higher in countries where citizens have to register in order not to be donors (85.9–99.98%), as they are registered by default, than in countries where citizens have to register to be donors (4.3–27.5%).

The purpose of these two interventions is to encourage the adoption of behaviours that would improve the social well-being. However, considering also the individual's well-being is essential to guarantee more acceptability of the intervention and consequently its success. Thus, we believe that in the evaluation of any intervention it is important to assess its impact on the participants' emotions and overall well-being. Actually, emotions appear to be an influential factor on the individual long-term engagement to the behaviour (Fishbein and Ajzen, 2011, p.247). Yet, few are the behavioural intervention studies that consider this aspect. For instance, a nudge intervention of calorie menu labeling in restaurants by Thunström (2019) underlines a significant effect of such intervention on emotions generating an "emotional tax" or an emotional cost for some nudgees expressing negative feelings, especially when they have less self-control over the concerned behaviour. Johnson and Goldstein (2003) also consider that in the case of default nudge to encourage organ donation there is an emotional cost specifically for those who must change their default setting.

Having a better understanding of the way emotions interact with behavioural interventions (Bruns et al., 2018), allows the establishment of more transparent, acceptable and efficient interventions. Relying on this understanding, we notice a small but growing literature about positive interventions (Quoidbach et al., 2015) allowing to build more personalised interventions.[4] This context motivated us to define as a second contribution of the present work assessing the way the two interventions impact positively or negatively the participant's emotions.

[4]Positive interventions are psychological interventions aiming to increase positive emotions or "happinness" in order to foster well-being.

4.3 Experimental design

4.3.1 Design

This experimental study[5] is based on a CG testing the influence of interventions on the relationship between intention and behaviour/donation. The experiment follows a between-within subjects design with three treatments: baseline, default nudge treatment and learning treatment (summary of the design in table 4.1). The whole experiment took place online by sending the participation links via e-mail and we administered it using the LimeSurvey Open Source survey tool (LimeSurvey Project Team / Carsten Schmitz, 2012).

A CG is a situation in which the participant earns her endowment before determining the allocation of this endowment between herself and a recipient. The recipient is a charity that receives the given share of the participant's initial endowment in the form of a donation.

We choose this game to study the intention-behaviour relation since we want to focus on pro-social and pro-environmental behaviours. Its simplicity allows us identifying clearly intentions and behaviours. In our case, the CG consists in the opportunity for the participant to share with a chosen charity an initial endowment of €10. We present three charities to which donations are possible: Croix-Rouge Française, Téléthon and Agir pour l'environnement. We choose these specific charities since we are interested in studying pro-social or pro-environmental behaviours. These charities defend social and environmental causes. The defined donations during this experiment are genuinely disbursed to the charities.

In order to have a sense of a long-term effect of the intervention, we organised the experiment in two related parts conducted in different points of time. Part 1 of the experiment took place in early July 2021, followed by a second part (Part 2) with a two-week interval (see the data collection timeline in appendix D.2). We measure intentions twice: first, at the beginning of the experiment (in part 1) in a 5-minute questionnaire, and second, two weeks later in part 2.

In this second part, we asked the participants to indicate twice their donation with two different initial endowments of €10. One of the two donations is then randomly selected at the end of the experiment to determine the final gains.

With this relatively long period between the two parts, we hope to measure the influence of our intervention in the long run and isolate only temporary effect on intentions and behaviour.

[5] We fine tuned the design of our experiment based on the results of a pilot study. Details about this pilot are presented in appendix D.3.

4.3.2 Treatments

The baseline is a classical CG done with an initial endowment of €10.

The learning treatment takes place at the very beginning of the experiment in part 1. We ask the participants to read a text about the different charities, take a quiz on the charity and write down a short text explaining why they think it is important to give to charity (see instructions in appendix D.4.1). Afterward, we ask the participants what donation they intend to give.

The default option treatment takes place in part 2. The intervention consists in a slider task with fifty movable sliders. Each slider refers to a donation of 20 cents. As a default, all 50 sliders are positioned to the right for a default donation of €10. Thus, if the participant does not slide back to the left the pre-positioned sliders to change the default setting, a donation of €10 is automatically given to the charity (A screenshot example is presented in figure D.3 in appendix D.4.2).[6]

Table 4.1: The experimental design

	Baseline	**Learning**	**Default nudge**
		Part 1	
	Intention measure (Int1)	**Learning intervention**	Intention measure (Int1)
		Intention measure (Int1)	
		Part 2	
	Intention measure (Int2)	Intention measure (Int2)	Intention measure (Int2)
Phase 1	Questions & choice of charity	Questions & choice of charity	Questions & choice of charity
	Behaviour (Don1)	Behaviour (Don1)	**Default nudge intervention**
			Behaviour (Don1)
Phase 2	Distraction task	Distraction task	Distraction task
	Behaviour (Don2)	Behaviour (Don2)	Behaviour (Don2)

Notes: Int1 and Int2: two measures, qualitative (seven-points Likert scale) and quantitative (in €)
Don1 and Don2: quantitative measure of the behaviour (in €)
Questions: Socio-demographic questions
Charities: Croix-Rouge Française, Téléthon and Agir pour l'environnement

4.3.3 Procedure

The sample is composed of "regular" individuals that are residents of Grenoble Metropolis (France) and that we recruited using the internal contacts' list of GAEL.

In part 1, we start by measuring participants' intentions to donate after explaining the game and presenting the charities to which it is possible to donate. We use two types of measures: a Likert scale measure and a measure of intended level of

[6]The slider task may relate more to a "taking" game than a "giving" game, as each slider removes 0.2 cents from the charity. However, Grossman and Eckel (2015) find that taking or giving are similar in the case of a charity game.

donation. For those participating in the learning treatment, we introduce at this level the intervention on intention that is based on the human reasoning system 2. For the two other treatments, we simply measure the intentions (see table 4.1).

After two weeks, the same participants are invited to participate in part 2 of the experiment that we organize in two phases. In phase 1, we start by remeasuring the intentions. To ensure that there is enough time between the moment of measuring these intentions and the moment of making a donation, we ask the participants to answer some socio-demographic questions and to choose the charity they would like to donate to. This donation could take a value between €0 and €10 with intervals of 20 cents for comparison purposes between the treatments. Next, we ask the participants to do the actual behaviour by donating to the chosen charity using the sliders. For those taking part in the default nudge treatment, we introduce the intervention at this level since we want to make an intervention that is based on the reasoning system 1 by nudging the behaviour. For the baseline and the learning treatment, the participants had just to insert the level of the donation in an empty box.

In phase 2, we test whether the interventions have an effect on subsequent decisions. We introduce a separation between the two phases by introducing a distraction task (a modified version of the Linda conjunction problem (Epstein et al., 1995; Tversky and Kahneman, 1983) that has no influence on the results of our design)[7]. Following this distraction task, we ask the participants to make a second donation on the bases of another initial endowment of €10 without asking for their intentions. All participants, whatever their treatment group, have to indicate the amount they want to donate by filling an empty box.

We complement the design of the experiment by measuring some psychological factors. The presentation of these variables and the used items to measure them are included in appendix D.5. we actually ask the participants about their emotions before and after completing the experiment. We use an adapted version of Positive and Negative Affect Scale (PANAS) (Watson et al., 1988): we present fourteen adjectives, seven of which describe positive emotions (eg. active, proud, enthusiast) and the others negative emotions (eg. ashamed, betrayed, angry). For each emotion, participants report how well the adjective describes their current emotional state on a five-point Likert scale (1=totally disagree to 5=totally agree).

Finishing the whole experiment lasted 30 minutes. Before starting the experiment, we informed the participants that they gain a minimum of €5 as a participation fee and that they could gain an additional maximum of €10 depending on their

[7]Linda conjunction is a well-know illustration of the conjunction fallacy where the individual judges incorrectly that the realisation of two possible events is more likely than one or both of the events.

decisions in part 2 regarding the level of donation. Thus, participants were paid only if they completed their participation in both parts. As previously mentioned, one of the two donations defined in part 2 is randomly selected. Hence, the participant gets [€5 + €10 - selected amount of donation]. Thanks to the participants' donations, the three charities got a total donation of €1,324.20. 351 subjects participated in part 1 with 117 participating in each treatment. At the end of the experiment we had a final sample of 312 participants who finished both parts with 34% in the baseline, 30% in the default treatment and 36% in the learning treatment.

4.4 Hypotheses

Conducting an online laboratory experiment with a repeated CG allows us to answer our research question. We assess the effects of the two interventions [8] (i.e learning and default). The expected effects on intentions, donation and the intention-donation gap are visualised in the table of figures 4.2. We formulate the hypotheses[9] depending on the baseline situation of either having a gap (H1) between intentions and donations or not having a gap (H2).

Learning treatment

Comparing to the baseline, and whether starting from a situation where there is a gap (H1a) or not (H2a), we first expect that the learning intervention applied only on intentions (Int1) would result in higher stated intentions compared to the baseline (Int1L>Int1). A similar intervention has been tested in an experimental study of Zaval et al. (2015). Their participants did an essay-writing exercise about what they wanted to be remembered for by future generations. It resulted in an increase of the intentions to donate to an environmental charity.

Second, following the TPB, influencing the intentions through the learning intervention results in the creation of new intentions that could consequently result in a change in the behaviour. We actually expect that the increased intentions would translate in an increase in the donations compared to the baseline (Don1L>Don1). This idea is in line with a vast literature that relies on the TPB to generate behavioural change (Ajzen and Schmidt, 2020). For example, Bazart et al. (2019) demonstrated in the context a public good game that interventions acting on intentions such as informing the subject about the benefits of contributing to the

[8] Figure D.1 in appendix D.1 summarizes our reflection process behind the choice of the intervention tools.

[9] We note here that in the presentation of the hypotheses, we consider the measures of intentions (i.e quantitative and qualitative) as a single measure of intentions called Int for baseline, IntL for the learning intervention and IntD for the default nudge intervention.

collective fund have resulted in significantly larger contributions compared to the baseline.

Other empirical evidences confirmed the efficacy of informative learning interventions (Saeri et al., 2022; Noetel et al., 2020; Butts et al., 2019) leading for example to more registration to organs or blood donations (Godin et al., 2012; Siminoff et al., 2009).

Third, we assess the effect of the learning intervention on the intention-behaviour gap. Comparing to the baseline case if there is a gap, we assume that this intervention would reduce the existing gap (GapL < Gap): the increase of intentions (Int1L) is followed by a larger increase in donations (Don1L). The participants become more aware of their intentions and the importance of giving, donations are going to increase as well and get closer to intentions. Less is known about the effect of this type of intervention in time but we believe that it is going to be a long term effect since we influence the defining variable of the behaviour (i.e the intentions). So, the changes should be deeper than in the case of intervention playing only in system 1 (Hertwig, 2017; Grüne-Yanoff and Hertwig, 2016; Grüne-Yanoff, 2018).

In case where there is no initial gap in the baseline, we expect that the learning intervention would not create a gap (GapL = Gap) giving intentions that are equal to donations (Int1L = Don1L). This could be justified by the fact that the donation behaviour is highly correlated with the intentions so they are followed. This assumption goes along the main statement of the TPB in which intentions are the direct antecedent of the behaviour.

Default nudge treatment

Regarding the participants taking part in the default nudge treatment, similarly, two groups of hypotheses are expected depending on the baseline presenting a gap (H1b) or not (H2b) between intentions and donations.

First, for both situations, since the nudge is only applied on the behaviour, no changes are expected for the intentions. Thus, we expect no significant difference between the intentions of participants taking part in this intervention compared to those participating in the baseline (Int1D = Int1 and Int2D = Int2).

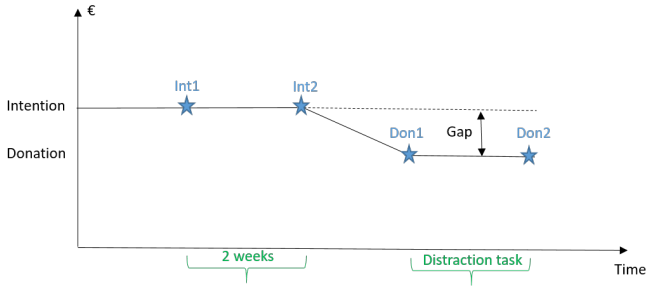
Second, the aim of this intervention is to increase the donations and possibly make participants adopt pro-social behaviours (corresponding to a donation of the entire endowment). We expect that the default nudge will result in higher donations than the baseline (Don1D > Don1). This prediction is grounded on existing literature demonstrating that when individuals are presented with a default setting, they will most likely keep it (Mertens et al., 2022). According to Dinner et al. (2011), defaults influence decisions through three psychological channels: endorsement, ease,

and endowment. That is, decision-makers are more likely to choose the pre-selected option because: 1) they believe that the pre-selected option is pointing the best option to them/or to the social norm; 2) they can exert less effort when staying with the pre-selected option; and/or 3) they will evaluate other options in reference to the pre-selected option with which they are already endowed (Dinner et al., 2011). The work of Ghesla et al. (2019) is an example of application of the default nudge demonstrating a significantly higher donations in the context of a dictator game. They actually tested two variations of the default nudge: 1) a classical default level of donation that could be changed by modifying the level already indicated in a cell or 2) the necessity to complete an effort task to be then able to modify the default or else donate the already defined amount. The first type of default nudge, let to a 25% increase in the average donations compared to the baseline. The second type of default allowed even larger donations with participants giving on average 114% more to charity than participants in the baseline. In another application, Momsen and Stoerk (2014) tested a number of nudge interventions on the choice of energy contract and found only the default nudge to be the most effective in helping the individuals to translate their intentions into action. The default setting allowed a 44% increase in the share of renewable energy contracts. Hence, a default setting appears to be suitable to use as it is mainly playing on behaviour and already demonstrated its effectiveness.

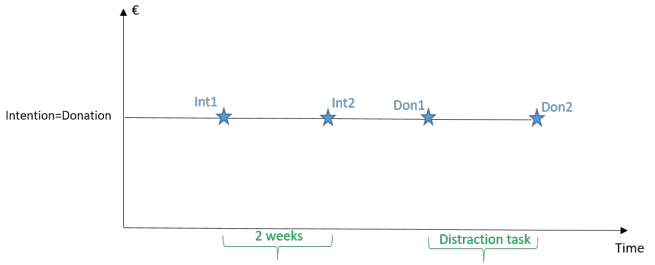
Third, if there is an intention-behaviour gap in the baseline, we expect that the increase of donations induced by the the default nudge intervention will bring closer the donations to the intentions which will reduce the gap (GapD $<$ Gap). Whereas if there is no gap in the baseline, the increase of donations will exceed the intentions creating an inverted gap (-GapD $>$ Gap).

However, we believe that the effects of the nudge are only temporary. Once the nudge is removed in the second part donations will get back closer to the baseline. This expected short term effect goes in line with existing literature that have previously confirmed this idea (Sunstein, 2017; Allcott and Rogers, 2014).

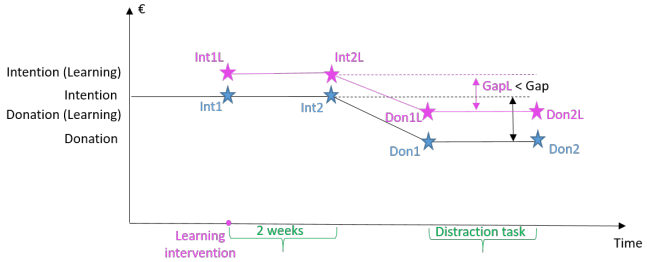
Table 4.2: Hypothesized interventions' effects



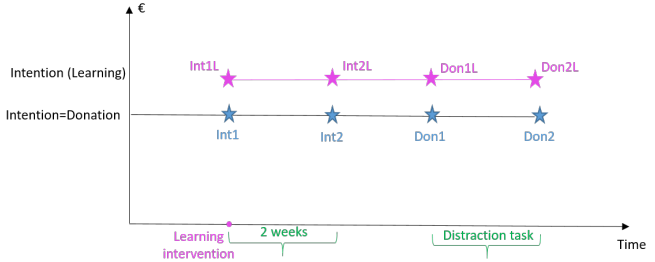
(a) Gap in the baseline (H1)



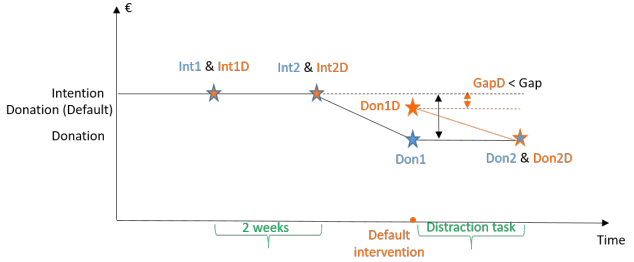
(b) No gap in the baseline (H2)



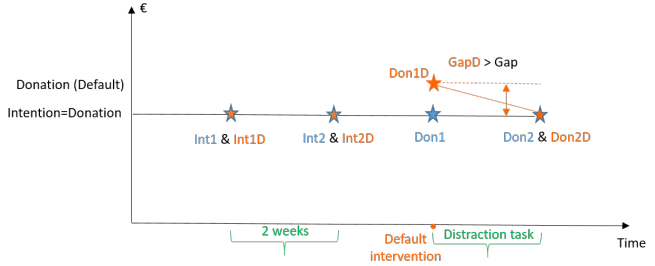
(c) Hypothesized effect of the learning intervention in case of a gap (H1a)



(d) Hypothesized effect of the learning intervention in case of a no gap (H2a)



(e) Hypothesized effect of the default intervention in case of a gap (H1b)



(f) Hypothesized effect of the default intervention in case of a no gap (H2b)

4.5 Results

We start this section by presenting the randomization check. Then, we determine whether we are in a situation with an intention-behaviour gap or not. Next, we present the effects of the two interventions on intentions and donations. Finally, we investigate the impact of the interventions on emotions.

4.5.1 Randomization check and descriptive statistics

In part 1, we had a sample of 351 participants divided equally between the three treatments (i.e 117 participants in each treatment). The final sample of those who completed part1 and part2 of the experiment is composed of 312 participants with 34% who are in the baseline (*n=106*), 30% taking part in the default treatment (*n=93*) and 36% being in the learning treatment (*n=113*).

We conduct randomization check to verify whether the three groups participating in each treatment are comparable in terms of demographics (gender, age, income and level of education). Table 4.3 presents a summary of the descriptive statistics of these socio-demographic variables. A Fisher's exact test reveals that the participants' gender differs significantly (p=0.039) between the three treatments. We actually have a higher share of female in the learning treatment (60.18%) compared to the two other treatments (around 45% are female). We also conducted a one-way ANOVA to compare participants' mean age per treatment. The mean age for each treatment is 38.3 years old (SD= 11.1) for the baseline, 37.3 (SD = 9.7) for the default treatment and 43.9 (SD = 11.8) for the intention learning treatment. These age differences between the treatments are significant (F=11.15, p=0.0000). The distributions of the income and of the level of education are not significantly different between the treatments. Performing a regression of the level of donation on age and gender show a non significant effect of these variables (see table D.5).

Table 4.3: Descriptive statistics of the socio-demographic variables

	All		**Baseline**		**Default**		**Learning**	
Observations	*312*		*106*		*93*		*113*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age	40.03	11.38	38.28	11.14	37.30	9.74	43.90	11.88
	Frequency	*Proportion*	*Frequency*	*Proportion*	*Frequency*	*Proportion*	*Frequency*	*Proportion*
Female (=1 if female)	158	50.64	48	45.28	42	45.16	68	60.18
Income (in €)								
Less than 1000	18	5.77	7	6.60	5	5.38	6	5.77
1000 to 1500	35	11.22	8	7.55	15	16.13	12	11.22
1500 to 2000	53	16.99	21	19.81	16	17.20	16	16.99
2000 to 3000	76	24.36	27	25.47	20	21.51	29	24.36
3000 to 4000	54	17.31	17	16.04	14	15.05	23	17.31
4000 to 5000	34	10.90	12	11.32	11	11.83	11	10.90
5000 to 6000	28	8.97	8	7.55	7	7.53	13	8.97
More than 6000	6	1.92	3	2.83	1	1.08	2	1.92
No answer	8	2.56	3	2.83	4	4.30	1	2.56
Education								
No diploma	14	4.49	4	3.77	4	4.30	6	5.31
Baccalaureate	46	14.74	15	14.15	15	16.13	16	14.16
Bac +2/+3	100	32.05	31	29.25	27	29.03	42	37.17
Bac+5 or more	152	48.72	56	52.83	47	50.54	49	43.36

Note: SD: Standard deviation

As mentioned in the design section, we elicited intentions to donate using two measures: the traditional psychological seven-points Likert scale measure (Int1quanli and Int2quali), ranging from 1=totally disagree to 7=totally agree, and a second measure (Int1quanti and Int2quanti) asking directly the amount of the intended donation on the bases of an initial endowment of €10. The observed behaviour, is the amount of donation in € (Don1 and Don2) and it is comparable to Int1/2quanti. We create two binary variables (Donate1 and Donate2) that take the value 1 if the participant gave a positive donation and 0 if he/she did not donate. These latter are more comparable to our qualitative measures of intentions Int1/2quali. A summary of the descriptive statistics of these variables is presented in table D.6.

We find a strong and significant positive correlation between the different measures of intentions and donations exhibiting a high predictive power for both measures of intentions. On the one hand, Int2quanti presents a significant positive correlation coefficient of r=0.93 with Don1, meaning that the measure of intentions explains 86.49% of the variances of the first donation.[10] On the other hand, Int2quali has also a high correlation , based on the literature (Sheeran, 2002), with Donate1 (r= 0.63) explaining 39% of the variances of the first donation.[11] The Spearman's

[10]The correlation between Int2quanti and Don2 is also considered high with a coefficient r=0.88, explaining 77.44% of the variances of the second donation. Int1quanti presents a correlation coefficient r=0.85 with Don1, explaining 72.25% of its variance, and r=0.80 with Don2, explaining 64% of its variance.

[11]Int2quali, also explains around 38% of donate2 and Int1quali explains 30.25% of the variance of donate1 and 18.5% of the variance of donate2.

correlation coefficients matrix[12] of these variables is presented in table D.7.

Since both measures are highly correlated to the donation, considering one or the other should give the same conclusions. Besides, the quantitative measure of intentions presents relatively better predictive power with stronger correlations to the donation. Thus, to ease the comparisons and the reading of the results, we decide to only keep the quantitative measures of intentions for the presentation of the remaining results. We refer to Int1quanti and Int2quanti, respectively, as Int1 and Int2.

Additionally, we identify a strong temporal stability of the measure of intentions based on the non significance of a Wilcoxon signed-rank test comparing Int1 to Int2 (z=0.517, p=0.6053). Having a strong temporal stability of intentions also indicates that our measure of intentions should be a good predictor of donations.

In this regards, we compare the intentions to the donations to determine whether the participants present a gap. We use only the data from the baseline group to isolate the existence of an intention-behaviour gap from the effect of the interventions. The comparisons results show no significant difference between the stated intentions in both parts of the experiment and the two donations defined in part 2.[13]

Hence, we can conclude that we are in a situation where there is no gap between intention and donation. This is also visible in the distribution of the means of intentions and donations in figure 4.1.

[12]We use Spearman's correlation measure because our data is not normally distributed, following the results of Shapiro-Wilk normality tests.

[13]In the baseline, the results of the Wilcoxon signed-rank test show no significant differences between Int1 and Don1 (p-value=0.8020), Int2 and Don1 (p-vaue= 0.7463), Int1 and Don2 (p-vaue= 0.1790) and Int2 and Don2 (p-vaue= 0.1734)

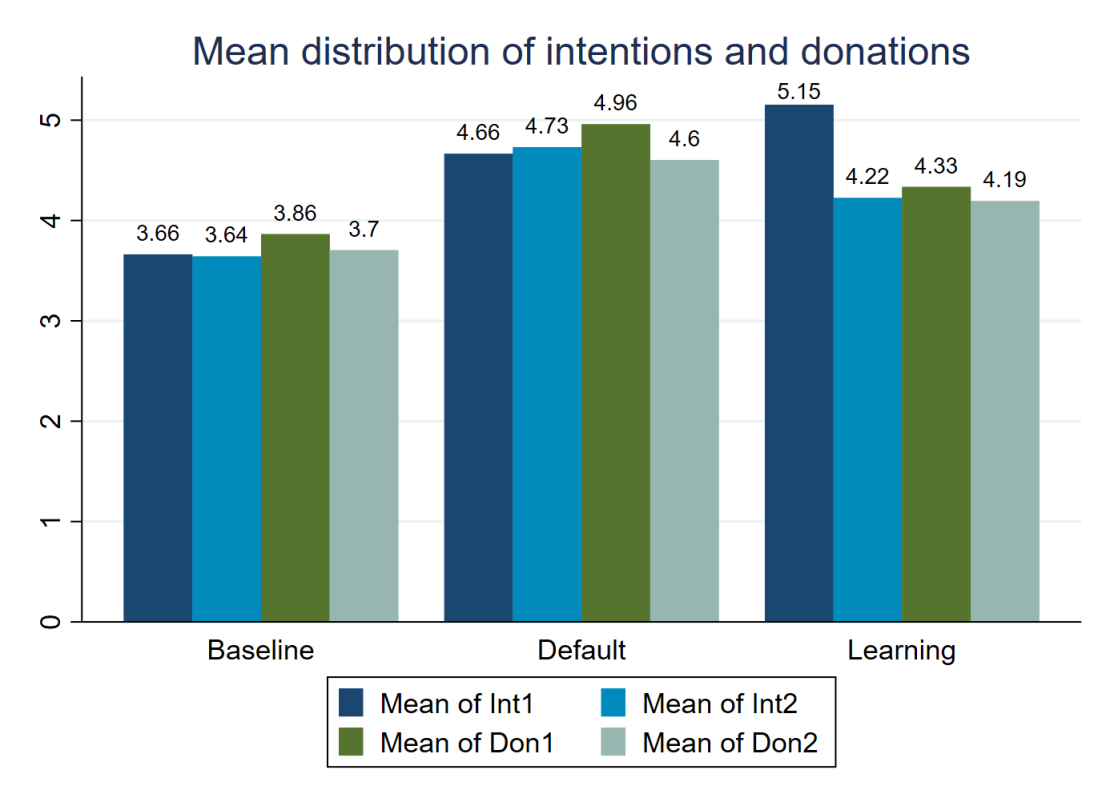
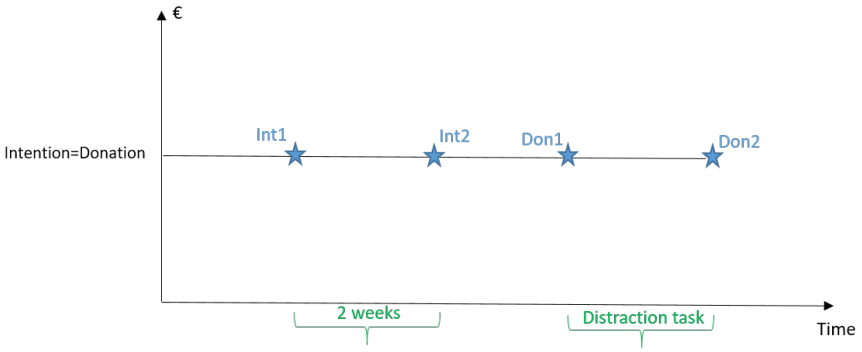


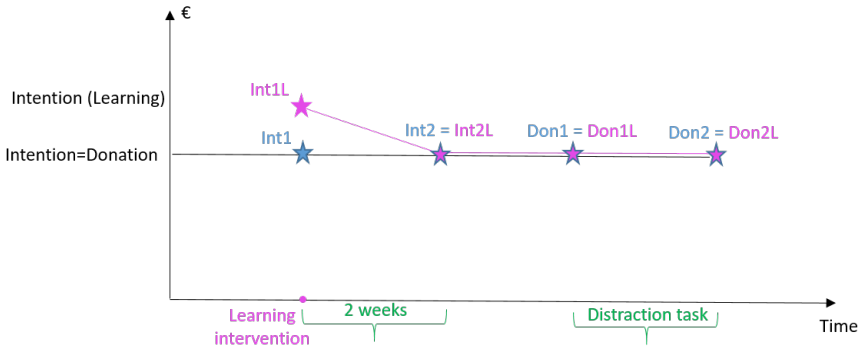
Figure 4.1: Mean distribution of the quantitative intentions and donations

4.5.2 Interventions effect

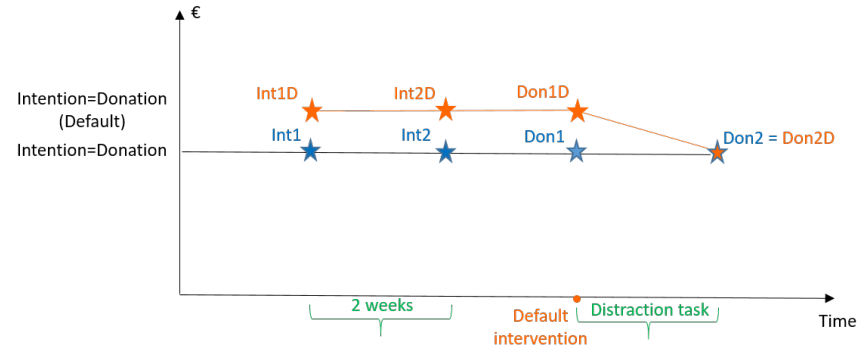
As we are in a situation where there is no gap between intention and behaviour, we drop the hypotheses of H1a and H1b. Assessing the effects of the interventions compared to the baseline, we perform a series of Mann Whitney tests. We test the statistical significance of the difference in the intentions stated in part 1 (Int1), the intention stated at the beginning of part 2 (Int2), and the donations (Don1 and Don2) realized during part 2 of the experiment.



(a) Results of the baseline



(b) Results of the learning treatment



(c) Results of the default nudge treatment

Figure 4.2: Results of the interventions' effects

4.5.2.1 Effects of the learning intervention

Hypothesis H2a, predicts that the learning intervention should increase the intentions compare to the baseline, which in turn should lead to higher donations, with no intention-behaviour gap. We did find significant evidence at 1% level that the intentions stated in part 1 in the learning treatment are higher than the ones stated in the baseline treatment[14]. However, two weeks later, when asking again for intentions (Int2), they were not statistically different than the ones of the baseline treatment (z = -0.81, p-value = 0.4210). This result indicates that the learning intervention had an impact on the stated intention in part 1 that was not strong enough to last in part 2 of the experiment: we have a temporary effect on intentions. The figure 4.1 presenting the mean distributions also confirms this result.

The donations (Don1 and Don2) realised in part 2 of the experiment are also not statistically different from the baseline treatment, based on the Mann-Whitney test for Don1 (z = -0.88, p-value = 0.3797) and for Don2 (z = -0.99, p-value = 0.3188).

Looking at the intention-behaviour gap, according to hypothesis H2a, the learning intervention should also not result in a gap. However, by temporary increasing the level of intention in part 1, the intervention created a gap of Int1 with the two donations in part 2.[15] Once that temporary effect has disappeared (i.e. when measuring intention in part 2) this gap disappears indicating that participants respected their intentions. Hence, these results weakly support the hypothesis H2a. They are summarized in figure 4.2b.

4.5.2.2 Effects of the default nudge intervention

Hypothesis H2b, predicts that the default nudge intervention should directly increase the donation compared to the baseline but not the intentions, creating an inverted gap between intentions and donations. The results show that the intervention increases the level of donation. We find statistically higher higher level of Don1 when compared to the baseline.[16] As expected, the effect is only temporary since once the default nudge is removed in the second donation, Don2 is not statistically different from the baseline (z = -1.77, p = 0.0775).

An unexpected result is the levels of intentions in the default treatment being higher than those in the baseline whereas no intervention has yet taken place when we measure them. The intervention actually occurs only on the behaviour (i.e. the default option is on the action to donate). The measured intentions in part 2 are

[14]Mann-Whitney test between Learning and baseline on the intentions measured in part 1, give a z = -2.67, p-value = 0.0077).

[15]We find significant Wilcoxon signed-rank test between Int1 and Don1 with z = 3.4, p-value = 0.0007.

[16]We performed a Mann Whitney test between Default and Baseline on the first donation Don1, this gives z = -1.99, p = 0.0458

statistically higher in the default treatment than in the baseline (z = -1.97, p-value = 0.0493) and almost significantly higher in part 1 (z = -1.9, p-value = 0.0568).

A potential explanation of this finding is the presence of a selection effect first resulting from the fact that we only consider the stated intentions of the participants who completed the whole experiment. We also believe that it is resulting from an observed higher attrition in the default treatment than in the other treatments. Over all the sample, thirty-nine participants who completed part 1 of the experiment did not finish the part 2 with the majority (61.54%) taking part in the default treatment. The attrition in the default treatment (20.51%) is statistically higher than the one in the baseline (9.4%).[17] This higher attrition could be due to the boring and tedious aspect of the default nudge task. This is the case even though it took in average only 3 minutes to perform the slider task for the participants who completed part 2. Hence, the default intervention may have selected the participants with the highest intentions.[18]

Regarding the intention-behaviour gap, we partially confirm the hypothesis H2b. We did not find the expected inverted gap: the intentions in part 1 and 2, and the first donation exhibit no significant difference (significant Wilcoxon signed-rank test between Int1 and Don1 with z = -0.74, p-value= 0.4617). However, we did find a significant decrease between the first donation and the second one (significant Wilcoxon signed-rank test between Don1 and Don2 with z= 2.053, p-value= 0.0401).

To summarise, the results indicate two complementary effects of this intervention: 1) a behavioural effect demonstrated by a higher level of donation compared to the baseline and the subsequent decrease of the donation when the default nudge is removed and 2) a selection effect demonstrated by a higher level of intention in the default treatment than those in the baseline. Hence, these results partly support the hypothesis H2b and and they are summarized in figure 4.2c.

4.5.3 Effects on emotions

In evaluating the effectiveness of the two interventions, we assessed their impact on the participants' emotions. Since we are in the case of a charity game, this type of game is likely to create positive emotions following the performance of the act of giving, called according to Andreoni (1990), the warm glow effect. Besides, both interventions play on two different reflection systems acting on different parameters. Thus, comparing their respective effects on emotions is also important from a well-

[17] Performing a proportion test we find a z = 2.38 (p-value = 0.02), between the default treatment and the baseline.

[18] Intentions of the participants who did not complete part 2 were lower than the intentions of those who completed (Int2D=3.6 for the people who left against Int2D=4.7 for those who completed the experiment), and there are significantly less totally pro-social individuals who left the experiment, it based on the Mann-Whitney test: z = 2.124, p-value =0.0336.

being perspective.

We asked the participants about their emotions before and after completing the experiment using an adapted version of PANAS (Watson et al., 1988)[19]. Using these measures, we created two scores, NE for negative emotions and PE for positive emotions.

We expect that the warm glow effect is expressed in terms of an increase (decrease) in positive (negative) emotions between the two moments of measurement of emotions. We also expect that the participants taking part in the learning treatment would express more positive emotions than those in the default nudge treatment. This assumption is justified by the fact that in the learning treatment the individual makes voluntary and conscious donations. Indeed, being mindful of his decisions has been found to be positively related to increased well-being (Thiermann and Sheate, 2020). Thus, our participants would express a higher level of positive emotions like pride or accomplishment. On the contrary, those facing the default nudge intervention would express a smaller level of positive feeling as the donation is not the result of conscious thinking but rather the result of the intervention on System 1, harnessing the status quo bias. We can even expect a higher level of negative emotions, such as betrayal, since there is a generally known and criticized lack of transparency (Bruns et al., 2018) in the implementation of such type of intervention. Participants could feel that they have been forced to donate a certain amount with the default option.

In our case, globally, the participants expressed more positive emotions than negative ones at both moments of measurement.[20] We find that over all the treatments, the scores of PE are significantly higher than NE (see table D.8 for the results of the Wilcoxon signed-rank tests).

To verify whether the variation of the declared emotions is significant between the two moments of measurement, we made a series of Wilcoxon signed-rank tests. The results of these tests are presented in table 4.4. We find that negative emotions decrease significantly for all treatments, but the levels of positive emotions did not increase. Since participants declared higher scores for positive emotions before even going through the experiment, we think that the increase in the warm glow effect may be reflected by the significant decrease in the negative feelings.

We create two variables Emo1 and Emo2 that refer to the variation of emotion with Emo1=PE1-NE1 and Emo2=PE2-NE2. The comparison of these two variables

[19]Cronbach's α of the first measure at the beginning of the experiment was 0.86 and 0.87 for the second measure at the end of the experiment.

[20]Mean positive emotions in the first measure (PE1) is equal to 3.54 (SD=0.74) and mean positive emotions in the second measure (PE2) is equal to 3.48 (SD=0.85). Whereas mean NE1 is equal to 1.7 (SD=0.72) in the first measure and the mean second measure of NF2 is reduced slightly to 1.6 (SD=0.71).

shows a significant and positive difference only for the learning treatment. Whereas, no significant difference is found in the default nudge treatment and in the baseline. This suggests that the intervention on intentions increases the awareness of the participant about the importance of giving to charities which in turn increases the warm glow effect from giving.

This is additionally confirmed by the significant difference that we find between the learning and default treatments when comparing PE2, using a Mann Whitney test, with more positive feelings for the learning treatment (z = -2.235, p-value = 0.0254; See table D.9 for the other comparisons.). Yet, the effect is small.[21]

Table 4.4: Variations of the levels of positive and negative emotions between the treatments

Z-value	Baseline	Default	learning
NE1 vs. NE2	3.168***	1.959**	4.31***
PE1 vs. PE2	0.465	1.319	0.336
Emo1 vs. Emo2	-1.238	-0.355	-2.895***

Notes: Test statistics of the Wilcoxon signed-rank test
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

4.6 Discussion and conclusion

In this study we conduct an online experiment testing interventions influencing the intentions, the donation and the intentions-behaviour gap to encourage more efficiently the adoption of pro-social or pro-environmental behaviours described through a charity game. The first intervention is a classical default nudge intervention that is based on System 1 reasoning process and the second intervention is a learning intervention that is based on System 2 reasoning process. In this section, we discuss the results of this experiment and their policy implications.

The results of the learning intervention tend to confirm that strengthening intentions in the short-term works but making this effect last in the long term is complicated. These results are comparable to the findings of previous studies. First, Gaudeul and Kaczmarek (2017) found also a short-term effect of their intervention manipulating intentions through a nudge intervention in a charity game. Their intervention allowed increasing the intentions but after two weeks they did not translate into increased actual donations.

There are also the results of Zaval et al. (2015) showing a significant effect of their cognitive effort task on intentions, which is similar to ours, allowing a following increase in the donations. However, in their design and contrary to ours, the

[21] Calculating the Rosenthal Correlation, we find a weak effect size r = -0.126.

donation directly follows the interventions on intentions.

We also believe that being in an experimental setting under a controlled environment made it easier for our participants to respect their declared intentions. In this context, the individual faces no constraint in the realisation of the behaviour allowing for stronger perceived behavioural control which is one of the most influential determinant of intention (Ajzen, 1991). Thus, the intentions were good predictors of donations resulting in no gap.

Thus, more studies are necessary to be able to conclude on the short-term effect on donation of the learning intervention. For instance, testing a modified version of the design of the present paper with the intentions directly followed by the donations would improve the comparability to the work of Zaval et al. (2015).

Regarding the default nudge intervention, we find an unexpected small behavioural effect on increasing donations and a significant effect on the attrition level. We believe that these results are partly due to the fact that the experiment was conducted online rather than in the laboratory. This setting makes it easier for the participants to quit during the experiment.

Previous empirical evidences (Jachimowicz et al., 2019) suggest that defaults are more effective when they operate through endorsement or endowment rather than an *effort cost*. *Endorsement* refers to presenting a default pointing out what the individual should do. Whereas *endowment* consists of introducing a default that is seen as a reflection of the status quo. Our results further confirm that including such effort cost that is relatively high (i.e tedious slider task) in a default nudge reduces the usual effectiveness of this type of intervention on charity. Thus, one need to be cautious in the design of this task as it may have an adverse effect and generates a strong attrition effect.

The identified small behavioural effect of our nudge intervention is different from the findings of previous similar applications. For example, Ghesla et al. (2019) implemented a default nudge intervention on the donation behaviour which significantly increased the donations but this experiment was done in the laboratory bringing students on site. Thus, even if the participant wanted to stop during the session, he could not leave before finishing the experiment. This setting allowed for lower attrition effect and for the sample of participants being not selected to include more willing donors.

This comparison of results emphasises the importance of considering intentions in the application and evaluation of nudge interventions. In our case, if we did not measure the intentions beforehand, we could only have identified the behavioural effects resulting in increased donations in the presence of the nudge and we could not have observed the selection effect due to attrition.

The results of this experiment contribute also to a better understanding of the

decision mechanism behind charitable giving by describing the way charity as a pro-social or pro-environmental behaviour relates to the reasoning systems 1 or 2. The initial dichotomous vision of using this model defining intentions and donations turns out to be limited. Since we find no gap between intentions and donations, this result indicates that in a charitable setting, intentions are well formed, preferences are already defined and they are respected. Thus, charitable giving, and more generally pro-social or pro-environmental behaviours, are the result of a sequential reasoning process where intentions are first defined through System 2 which are then followed by doing the behaviour based on System 1. This finding goes in line with the conclusion of the meta-analysis of 22 experimental studies done by Fromell et al. (2020) where they state that there is "little support for dual-system theories of altruistic behaviour" and that the two systems are not in conflict but could give the same outcome. In fact, "intuitive and deliberate thinking around donations are usually aligned" Saeri et al. (2022).

Despite the demonstrated utility of both interventions with positive effects on intentions and donations, the short-term effect suggests that improvements should be undertaken to guarantee a long-term positive effect. For example, in the learning intervention, raising awareness and giving the subjects the space to think and give their opinion about the behaviour had a temporary significant effect. To maintain this effect, we may need a recurrent commitment of the individual.

The findings on the effect of these interventions on emotions could also be harnessed to maintain the positive effects of the behavioural interventions. The fact that donating maintains the positive emotions and reduces the negative emotions could be used as an additional incentive to encourage the adoption of socially desirable behaviours. The public authorities could properly use this positive effect on individual and public well-being. This result is in line with the recommendation of Butts et al. (2019) and Noetel et al. (2020) who suggest highlighting the pleasure and the emotional rewards that giving generates to effectively encourage more donations.

General Conclusion

5.1 Main results

This thesis has contributed through economic and psychological theories to a better understanding of the individual determinants (socio-demographic, psychological and trip-related, with less interest in the infrastructure-related factors) to use active modes (public transport, bicycle and walking). This research topic is important given the proven negative environmental (eg. air pollution and climate change) and health externalities (eg. respiratory and cardiovascular diseases, sedentarity, premature deaths) of motorised vehicles.

Encouraging modal shifting to active mobility has been identified as a valid strategy to encounter these externalities. Public initiatives, such as the Climate and Resilience Act that mandates LEZs, allow for a legal context favorable to discuss ways to favor modal shifts to active modes and the challenges that come with this goal.

Modal shifting to active mobility is, both, a pro-social and pro-environmental behaviour. The thesis answers the central question: how could we use behavioural insights to identify public policy levers to promote the adoption of less polluting and active modes of transport as being a pro-social and a pro-environmental behaviour?

To answer this question, the thesis takes Grenoble Metropolis as a study area. This is a relevant area since it is still characterised with high levels of air pollution despite the significant political will. Indeed, local authorities continue to make efforts to encounter the negative environmental and health externalities of road traffic. Grenoble Metropolis is introducing new air quality improvement measures or developing existing ones. For instance, they are considering to extend the LEZs limiting the circulation of polluting freight transport to restrict all polluting vehicles.

The thesis was divided into four chapters each based on original data collected with different data collection methodologies (phone survey, internet survey, DCE and online laboratory experiment). To answer the main research question, an inter-disciplinary approach was adopted throughout the chapters to analyse these data using economic and psychological theories. The following is a presentation of the main results of the chapters allowing to formulate public recommendations in the

next section.

Firstly, considering that the people acceptability is a determinant of the success of the public air quality improvement measures, the acceptability of the project of implementing LEZs in Grenoble was assessed in chapter 1. This assessment demonstrated a general acceptability of this measure from the residents of the metropolis. However, there was a significant difference between the determinants of acceptability when comparing the supporters to the opponents. Supporters had more positive attitude and perception of the LEZ. Besides, it is more likely for an opponent to own a Crit'Air sticker impacted by the circulation restrictions. The socio-demographic factors play a less significant role in determining the acceptability of the LEZ.

Secondly, chapter 2 focuses on the modal shift motivation-intention relationship based on the SDT framework and the role of active mobility habits in this relationship. Distinguishing between the SDM (i.e. feeling of pleasure, belief in the usefulness and importance of modal shift) and NSDM (i.e. social pressure, fear of being criticized or judged), only SDM is positively related to stronger intentions to modal shift. Once active mobility habits are included in this relationship, none of the motivations were directly related to the intentions. However, SDM is strongly and positively related to habits. On the contrary, NSDM is negatively correlated with active mobility habits.

Thirdly, chapter 3 tests the influence of providing information about the morbidity risks of mobility practices on modal shift intentions. Based on a discrete choice experiment, information about the individual and public risk reduction for developing a cardiovascular disease significantly impacts the participants intentions. Thus, we find a positive relation between health risk reduction and intentions to modal shift. This effect is influenced by a conformity effect. However, the simple display of the health related information seems to have an effect without taking into account the exact reduction rate.

Lastly, taking a broader perspective than the study of modal shift, the chapter 4 tests public interventions applicable not only to the transport field but also to encourage any pro-social or pro-environmental behaviour. In the context of a charity game, a learning intervention is applied on intentions to donate and a default nudge intervention is applied on the donation behaviour. Both interventions had only temporary effects: the learning intervention significantly increased intentions but did not translate into real donations and the default nudge increased only the first donation with a significant attrition/selection effect. However, with both interventions negative emotions decrease after making the donation. This variation is more significant for the participants in the learning intervention compared to those in the default nudge intervention.

5.2 Public recommendations

The results of this thesis bring out behavioural insights that could be used to assist public authorities in the design of acceptable and more efficient air quality improvement measures. It should become a common practice for the public authorities to include behavioural insights in the establishment of "classical" measures (i.e pricing, infrastructure, regulation) in combination with behavioural change interventions (i.e nudge, communication, awareness). Indeed, it further ensures the success of the public measures and sustainably orient individuals toward socially desirable behaviours.

The public recommendations that could be made based on the results of this thesis are three-fold. First, policy makers should become aware of the implications of the implemented public measures on the targeted population. The social issues and population-differentiated impacts of policies restricting traffic in urban areas continue to be debated. The acceptability of measures, such as LEZs, is a central factor in the political feasibility of ambitious and environmentally effective measures.[22]. In particular, researchers and politicians are questioning the inequalities for the access to the environmental and health benefits between residents of the zone compared to those living out of the zone. Besides, the restrictions made on the most polluting vehicles usually target older cars which are usually owned by the most financially precarious shares of the population. Thus, identifying the most impacted populations by such measures through acceptability studies is essential to design the proper accompanying measures. The results of our study on the acceptability of the LEZs in Grenoble show that La Metro should improve the public transport network and services to ensure better physical and economic accessibility to these modes. In turn, it will allow further modal shifts to active mobility. Besides, the perceptions and attitudes of the residents of Grenoble seem to be most influential factors to the acceptability of the LEZs. Hence, interventions influencing these determinants like information provision or persuasive communication (Hamilton and Johnson, 2020; Bazart et al., 2019) could be considered.

Second, policy makers should use communication campaigns with relevant messages to, both, ensure further acceptability of the targeted population and promote modal shift to active mobility. The results of the present thesis demonstrated that public authorities should use positive messages about the utility of active mobility and the enjoyment/satisfaction that the individual could obtain from modal shifting. This would increase the SDM which could generate stronger active mobility habits and intentions to modal shift. Testing the use of positive messages with the provision of information about individual and public cardiovascular risk reduction

[22]https://theconversation.com/les-francais-de-plus-en-plus-preoccupes-par-la-qualite-de-lair-113798

thanks to modal shifting has proven to be a valid public measure to promote active mobility. In this regards, policy makers should communicate clear and simple messages about this risk reduction without necessarily specifying the exact reduction rate. On the contrary, negative messages relying on shaming, guilt and social pressure should be avoided. These messages are related to NSDM which have a counterproductive effect on active mobility habits and intentions to modal shifting.

Finally, policy makers should implement behavioural interventions to assist the individuals in translating their declared intentions into actual desirable behaviours. This assistance could take different forms. On the one hand, and relying on the results of the present thesis, if authorities decide to design interventions acting on the intentions, these ones should be more salient than the learning intervention tested in the experiment. This would guarantee a more sustainable effect in time which in turn increases the probability of the behaviour being adopted. On the other hand, if the authorities decide to design a nudge acting on the behaviour, adding effort (i.e slider task in the experiment) should be avoided. Indeed, if not designed carefully, the nudge intervention could be counterproductive resulting in more refrain from the encouraged behaviour. With both types of interventions, doing a pro-social or a pro-environmental behaviour allowed the reduction of negative feelings of the participants. Policy makers should make the individuals more aware of the emotional reward after engaging in such behaviours. This could be considered as an additional individual incentive motivating modal shifting (i.e SDM). However, to guarantee larger emotional reward, interventions on intentions are preferable.

5.3 Limitations and future research

More specific limitations and possible research extensions have been previously discussed in each chapter. Here, we present more general ideas that have impacted the whole thesis. We mainly focus on data collection/analyses challenges and the influence of the world's context on this research work.

First, choosing Grenoble Metropolis as a study case allowed us to collect a significant quantity of data about its residents. However, the city and its inhabitants present some specificities compared to other French or European cities. For instance, the fact that Grenoble is the flattest city in France and that it is characterised with a well-developed cycling paths' network ("Chronovélo" is 49 kilometers long), make cycling easier and safer. Besides, through our phone survey we found that around 61% of the sample declare being interested or very interested in air quality issues in Grenoble. This indicates a certain environmental awareness or preoccupation that influences mobility practices (Bouscasse et al., 2018). This public preoccupation is not necessarily present with other populations. Indeed, the French population ex-

presses different levels of concern in regards to air pollution depending on the area of residence. The surveys conducted by the French Ministry of the Ecological Transition in 2021 show that problems related to air pollution and the deterioration of the living environment were mostly listed by respondents living in big metropolitan areas (Ministère de la Transition Ecologique, 2021) like Grenoble Metropolis. Thus, similar analyses to the ones conducted in the present thesis should be replicated in other cities more or less populated than Grenoble for comparison purposes.

Second, using declarative data with a stated preference survey allowed us to collect data about individual mobility practices which are very personal information and not easily accessible. However, this data collection method has its own shortcoming, especially the risk of hypothetical bias. We tried to control this bias by asking accurate and easily formulated questions as well as building personalised scenarios in the DCE of chapter 3. The data collected during the thesis could also be enriched by combining it with revealed preference data or field experiments. The present thesis was conducted as part of the large interdisciplinary project Mobil'Air. The data that will be collected in some of the composing studies of Mobil'Air and their results would allow to get closer to the field and could complement the conclusions and recommendations of this thesis. For instance, the project RESMOB[23] evaluates the influence of peer effect in the working environment on mobility practices. Additionally, the project called Intermob[24] is a 24-month field study aiming to encourage the choice of alternatives to the car and collects data through mobility and physical activity sensors (GPS/accelerometer) as well as pollution exposure sensors.

Third, the world's context and the unexpected events that happened during the realisation of this thesis have inevitably impacted its outcomes. The data collection from the phone and online surveys were conducted in 2019 before the COVID-19 world pandemic and the online laboratory experiment was conducted in 2021 during it. With people remote-working and social distancing, this external shock has demonstrated a significant effect on changing the transportation practices (Campisi et al., 2020; Kalter et al., 2021). This situation lead to the reinforcement of active mobility habits. Thus, it would be interesting to conduct further surveys on habits and motivations, and satisfaction with the practice of active mobility after the pandemic.

The COVID-19 pandemic disrupted the individual mobility habits. This situation opened a window for some European policy makers to introduce some policies encouraging active mobility hoping for less public resistance. The review of Nalm-

[23]https://mobilair.univ-grenoble-alpes.fr/projets-associes/projets-associes-743738.kjsp

[24]https://mobilair.univ-grenoble-alpes.fr/vous-vous-interrogez-sur-vos-modes-de-deplacements-quotidiens-vous-souhaitez-diversifier-vos-modes-de-transport-et-reduire-l-utilisation-de-la-voiture-cette-etude-est-faite-pour-vous–773153.kjsp

pantis et al. (2021) ranks Paris as the city with the most introduced number of active mobility measures during the pandemic, followed by cities like Milan, Brussels and Berlin. In these cities, a focus is made on developing cycling. During the pandemic, Paris added more than 50 kilometers of temporary "corona cycleways" to the existing cycling network. The city intends to further develop these cycling lanes to become permanent. Besides, the government is implementing the project "'Plan Vélo" since 2019, which has four objectives: 1) improve the performance of the bicycle network (network, visibility, safety) and encourage daily trips, 2) improve the supply of bicycle parking, 3) develop services for cyclists and 4) promote the cycling network and communicate about cycling. The health context and the economic slowdown, combined with active mobility encouraging measures, resulted in significant reductions in CO_2 emissions (9% reduction between 2019 and 2020)[25]. There were also reductions in NO_2 annual mean concentration of up to 25% in major cities in France, Italy and Spain in 2020. During the first lockdown in April 2020, NO_2 concentrations monitored at traffic stations even fell by up to 70% (EEA, 2022a). Unfortunately, these reductions were only temporary[26] as they do not reflect structural changes in the economic, transport or energy systems (Le Quéré et al., 2020).

In addition to the COVID-19 pandemic, the recent Russia's aggression against Ukraine has led to concerns related to the security of energy supply in the European Union. The war resulted in a spike of oil prices reaching $110 per barrel in March 2022 and it is still increasing (World Economic Forum, 2022). This context is another shock that influences the individual mobility practices. An increase in the fuel prices significantly reduces the distance driven by private vehicles (Alberini et al., 2022) and influences the shift of preference from private to public transports (Ladin et al., 2015). The high prices also improve the economics of alternatives to the classical car like electric or hydrogen vehicles (World Economic Forum, 2022).

The current world context naturally influences the mobility practices but less is known about the long term effect of the pandemic and whether these changes are long lasting. Thus, making comparative studies with post-pandemic data is necessary to assess the validity of the results of the thesis before and after these events. We notice that politically speaking, managing the COVID-19 crisis and the energy security and affordability are currently at the top of the political agendas. Whereas climate change and sustainability are not a priority. This is a critical situation since pandemics and wars are considered still manageable challenges (EEA, 2022b) compared with the environmental and health disruptions that may lie ahead

[25]https://www.statistiques.developpement-durable.gouv.fr/estimation-de-lempreinte-carbone-de-1995-2020

[26]https://www.unep.org/news-and-stories/press-release/covid-19-caused-only-temporary-reduction-carbon-emissions-un-report

if we do not act immediately.

Appendix A

Appendices chapter 1

A.1 Classification of the Crit'Air stickers

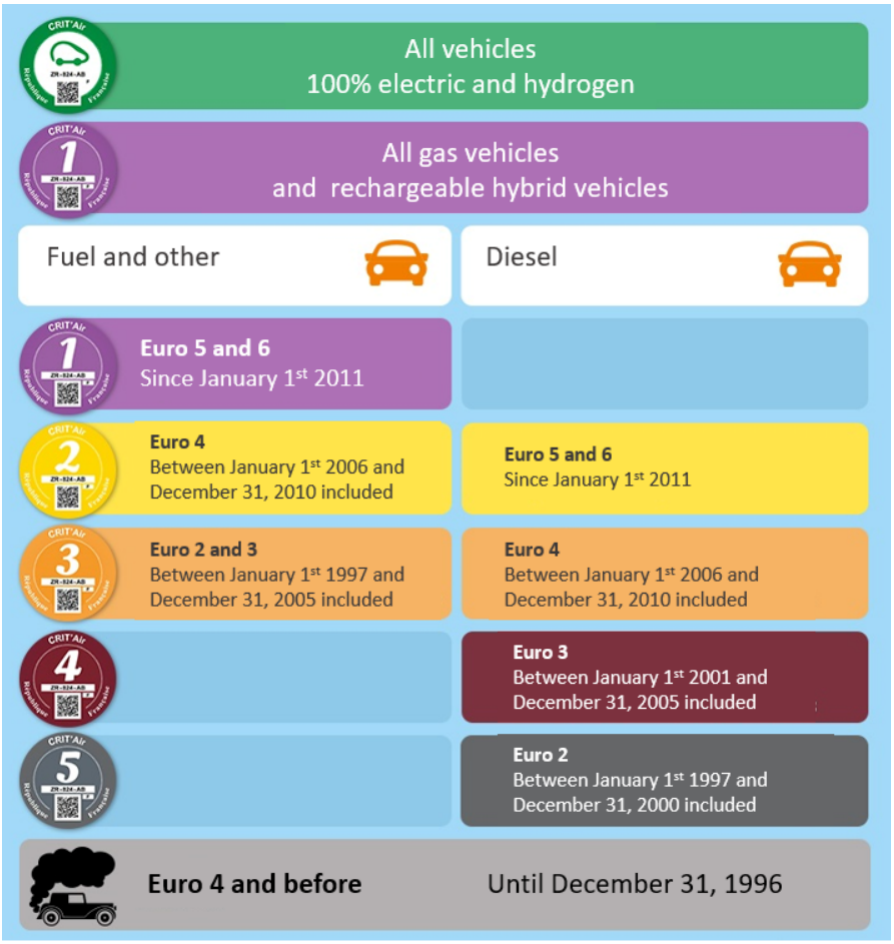


Figure A.1: Classification of the Crit'Air stickers (Source: Translated to English from www.portail-cartegrise.fr)

A.2 Map of Grenoble Metropolis and adjacent cities Grésivaudan and Voironnais

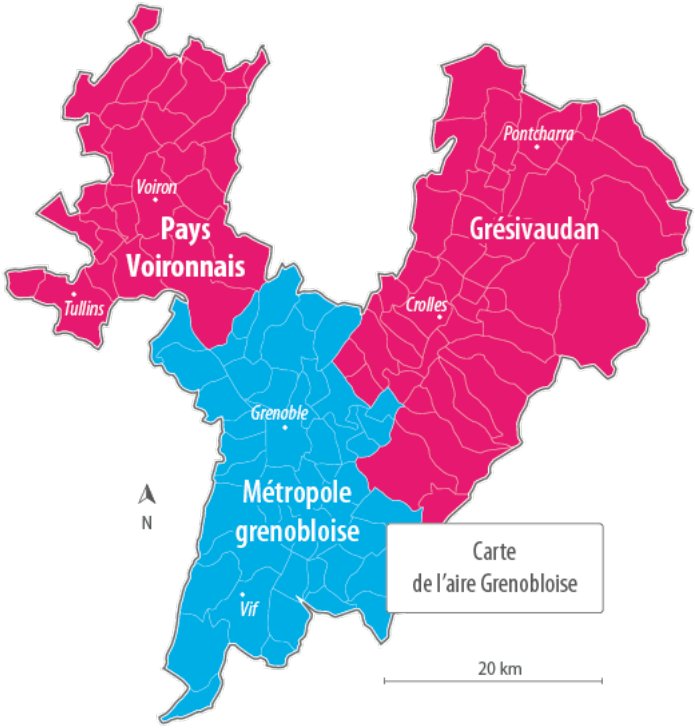


Figure A.2: Map of the surveyed zones: Grenoble Metropolis and adjacent cities Grésivaudan and Voironnais (Source: https://www.tag.fr/425-sur-mesure-grand-grenoble.htm)

A.3 Data calibration of the phone survey

To ensure a better representativity of the population of Grenoble through our sample, we calibrated the collected data. It is a technique originally developed by Deville and Särndal (1992) that "can be used to adjust a sample, through individual re-weighting using available auxiliary information for a certain number of variables, known as calibration variables" (Sautory, 1992). Calibration variable are assumed to influence the answering mechanism of the participant.

In our case, the calibration variables are the age and level of mobility [1] (mobile / less mobile). We gather ancillary information about these variables from the French population census of 2016 (INSEE website). We note that we did a stratification

[1] We describe the level of mobility of the observed individuals using their occupations. We suppose that an individual is "mobile" in case he/she has a professional activity or he/she is, a pupil, a student or an unpaid trainee. We assume that such categories of people will probably make a high number of trips to go to work or to study. In parallel, we suppose that an individual is "less mobile" if he/she is unemployed, retired or pre-retired, a housewife or man and in any other inactive situation.

Zone*Gender (Zone = A to D and Gender= 1 for man and 2 for woman), meaning that we have 8 strats. Based on this stratification and the ancillary data, we calculate the population totals presented in table A.1. We use these population totals to calculate initial individual weights d (also called design weights) which is the inverse of the probability of inclusion following the equation A.1, with $N_{zone*sexe}$ the population size in a specific strat and $n_{zone*sexe}$ the sample size in the same start. The resulting weights are presented in table A.2.

$$d = \frac{N_{zone*sexe}}{n_{zone*sexe}} \tag{A.1}$$

To generate the calibrated weights of these initial weights, there exists in the literature a number of calibration methods. We identify mainly four methods (Linear, Raking ratio, Logit and Linear bounded) that we test and compare between each other. The choice of the method cannot be based on a criterion of precision of the estimators, because the methods are all asymptotically equivalent (Le Guennec and Sautory, 2002). We end up choosing the Logit method with upper bound U= 1.9 and lower bound L=0.1. The extremes of L and U are found by successive trials with L increased toward 1 and U decreased toward 1 (Le Guennec and Sautory, 2005; Deville et al., 1993).

To make this data calibration there exists different tools. The most popular one is SAS (macro CALMAR). However, we also find open source software like R (icarus package) or Calif (of the Statistical Office of the Slovak Republic) among which we finally chose Calif v4.0. This preference is justified by the fact that Calif presents the advantage of taking into consideration the calibration margins of the strats contrary to icarus where only the totals of the categories of the variables are used. Therefore, Calif seems to be more precise and more informative in the presentation of its results (Rebecq, 2016; Calif (2018), 2018). These results are presented for the Logit calibration method in figure A.3.

Table A.1: Data of population totals for calibration variables

	RAGE_1	RAGE_2	RAGE_3	OCCUP_1	OCCUP_2
A1	10,879	30,072	18,417	34,743	24,626
B1	10,254	37,472	30,068	44,200	33,595
C1	3,100	14,547	11,802	17,944	11,506
D1	6,918	35,732	28,685	43,249	28,087
A2	11,833	32,709	20,032	37,788	26,785
B2	11,090	41,119	33,202	48,544	36,867
C2	2,966	14,207	11,773	17,525	11,422
D2	7,412	38,170	30,758	46,155	30,186

RAGE_1 : 18 to 24 years
RAGE_2 : 25 to 54 years
RAGE_3 : 55 years and more
OCCUP_1: Mobile
OCCUP_2: Less mobile

Table A.2: Distribution of design weights (d)

	N_{zone}	Quotas population	n_{zone}	Quotas Alyce	Inclusion probability	d
A1	59,369	12%	186	14%	0.00313296	319.186613
B1	77,795	16%	215	16%	0.00276369	361.835116
C1	29,448	6%	84	6%	0.00285245	350.576071
D1	71,335	14%	146	11%	0.00204667	488.598904
A2	64,574	13%	188	14%	0.00291139	343.478883
B2	85411	17%	239	18%	0.00279825	357.36682
C2	28,946	6%	91	7%	0.00314378	318.088571
D2	76,340	15%	155	12%	0.00203039	492.517226
Total	493,218	100%	1,304	100%	0.00264386	378.234678

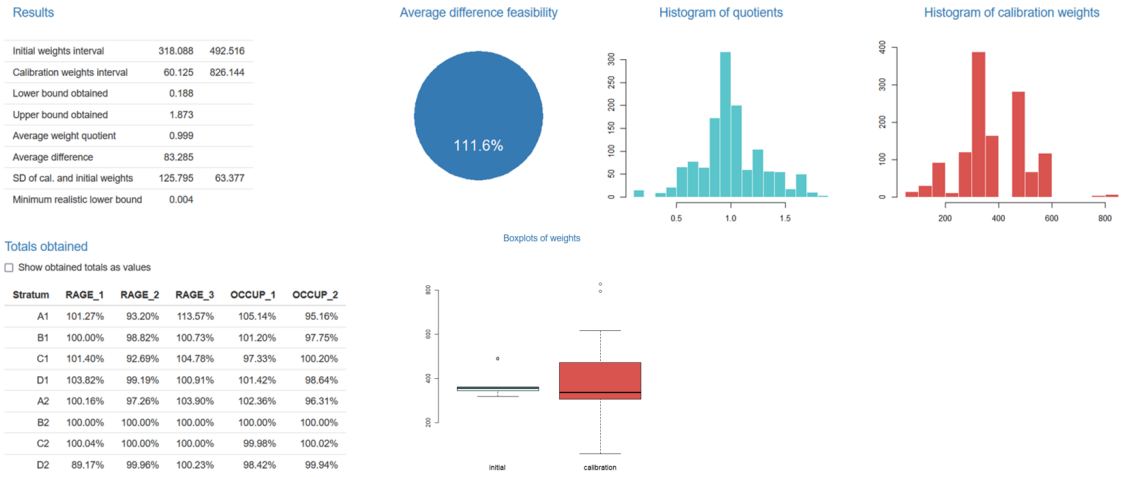


Figure A.3: Calibration output in Calif for the Logit bounded (U=1.9, L=0.1) method

A.4 Survey questions about adaptation behaviour to the LEZ and accompanying public measures

Table A.3: Survey questions - Adaptation and accompanying measures

Variable	Survey question	Response categories
Adaptation behaviour		
If pre-1997 petrol vehicles and pre-2006 diesel vehicles (vehicles with a Crit'Air 4 or 5 sticker) like the ones you own were banned,for the following trips, please tell us the most likely behaviour you would adopt...		
Q1	To get to your place of work / study	Bus, Tram, Bicyle, Walk, Car sharing, Risk paying a fine, Change car, Park the car at the limit of the zone, Change itinerary
Q2	To do your grocery shopping	Bus, Tram, Bicyle, Walk, Car sharing, Risk paying a fine, Change car, Park the car at the limit of the zone, Change itinerary, Change destination, Cancel trip
Q3	To do your other shopping	Bus, Tram, Bicyle, Walk, Car sharing, Risk paying a fine, Change car, Park the car at the limit of the zone, Change itinerary, Change destination, Cancel trip
Q4	For your leisure	Bus, Tram, Bicyle, Walk, Car sharing, Risk paying a fine, Change car, Park the car at the limit of the zone, Change itinerary, Change destination, Cancel trip
Accompanying measures		
If this project were to be carried out in the Grenoble metropolis, it would be accompanied by various measures to help the people concerned to adapt. For each of the following measures do you think it is useful?		
Q1	Scrappage assistance to buy a newer vehicle	1.not at all useful to 5.useful
Q2	Improvements to the public transportation system within the area	
Q3	Improvements to public transportation system outside the area	
Q4	Exemptions for people with disabilities	
Q5	Exemptions for certain public utility vehicles	
Q6	Exemptions for artisans and itinerant merchants	
Q7	A reduction in the price of public transport	
Q8	A one-way ticket for all public transport throughout the department	
Q9	Development of bicycle lanes	
Q10	The installation of more and larger park-and-ride facilities near public transport networks	
Q11	Authorization to drive in case of carpooling	
Q12	Personalized advice on different travel solutions	

Appendix B

Appendices chapter 2

B.1 Detail of the Exploratory factor analyses

Carrying out an EFA allows us to validate scales of items in a questionnaire and derive a construct (e.g. Habits) for a group of items (e.g. Q2 to Q14). This statistical technique is done following a number of steps (Samuels, 2017).
We start by doing a serious of tests verifying the adequacy of doing an EFA on our data. First, factor analyses is based on the correlation matrix of the studied items. We find that the bi-variate correlation scores of these items are all below 0.8. Field (2013) suggests removing items that exceed this level of correlation.
Second, we check the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test) verifying the adequacy of the sample size. We have a KMO above 0.8, more than the required 0.5 (Kaiser, 1974). We also apply the Bartlett's test of sphericity (Bartlett, 1950) testing the hypothesis H_0 that the correlation matrix is an identity matrix. The test is found significant at 5% level meaning that we could reject H_0. Lastly, the determinant of the correlation matrix is equal to $0.01 > 0.00001$ (Field, 2013) meaning that we do not have a multicollinearity problem.
The results of all these tests allow us to conclude that with our data we can perform an EFA.

We identify 3 factors with an Eigenvalue above 1 (known as Kaiser's stopping rule). The cumulative percentage of the variances of these factors is 60.04% which reaches just the recommended level for an EFA (Brown, 2009). A Varmax orthogonal rotation of our factors allowed us to better define the 3 factors that meet our theoretical model. Each factor is composed of a minimum of 4 items and has a factor loading above 0.4 (Samuels, 2017). We finish our EFA by verifying the internal consistency of the 3 identified latent constructs by calculating their Cronbach's alpha coefficients (α). For this test, a coefficient of 0.6 or above suggests a good

level of internal consistency of the factor (Ursachi et al., 2015).

Appendix C

Appendices chapter 3

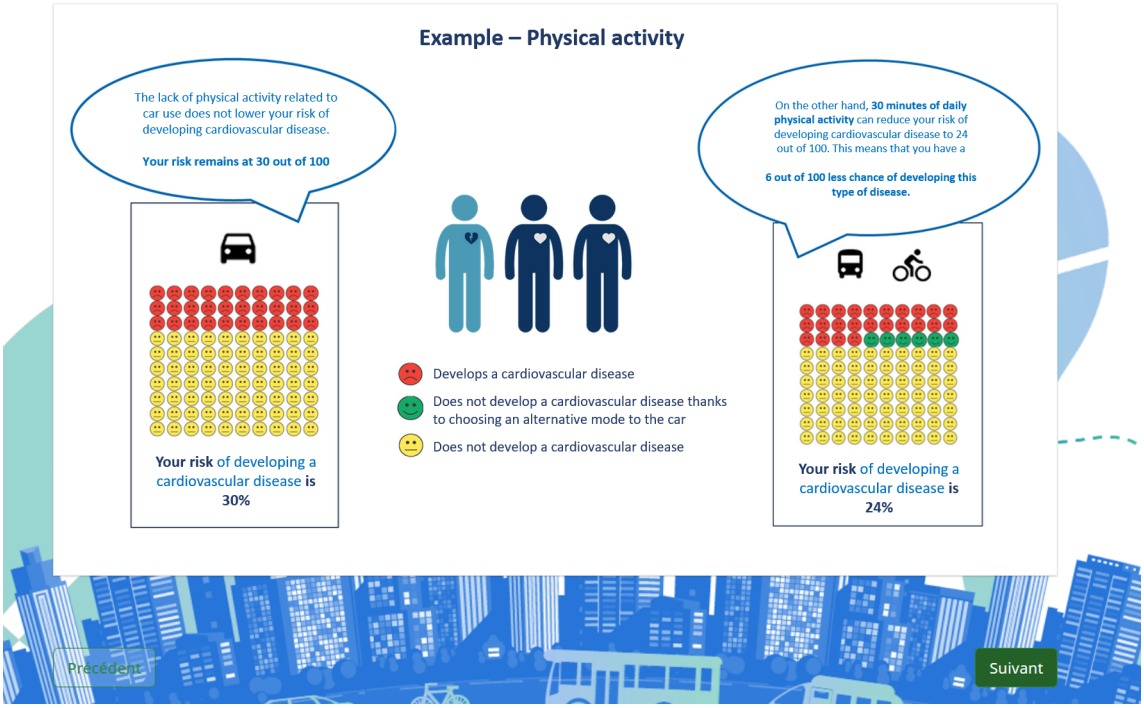
C.1 Map

Translation: "Can you tell us the area in which your place of departure is located? To do so, you must CLICK ON THE corresponding AREA on the map below (the outlines are displayed in blue). If necessary, you can use the location help by entering the address of the place but you will still have to CLICK ON THE AREA to validate the search."

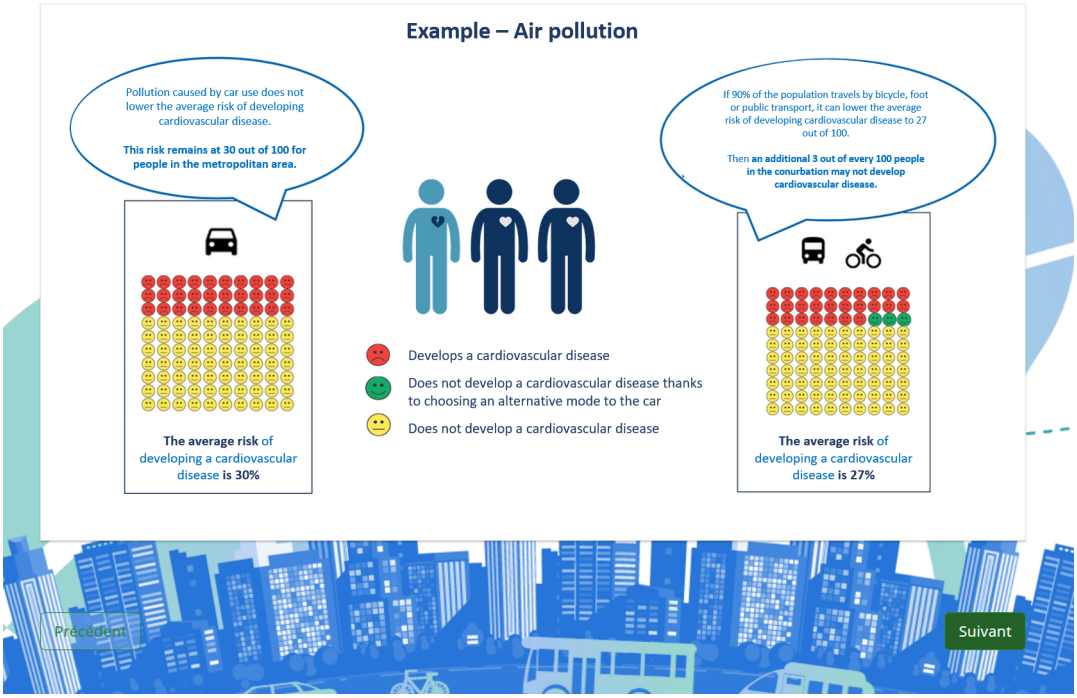
Please note that the starting point of your trip must be within the areas shown on the map below.

If you do not find your starting point, it is because the city of the starting point is not in the Grenoble metropolis. In this case, please indicate another trip for which you make at least three round trips per week or answer “No” to the question “trip within the Metro”.

C.2 Individual health attribute



C.3 Public health attribute



C.4 Example of a choice exercise

Mode of transport				
Travel time	10 min	9 min	17 min	9 min
Travel cost	1,5€	0,5€	0€	0€
Physical activity *Using this mode daily, your risk of developing a vardiovascular disease is*	24%	30%	24%	28%
Air pollution *If 75% of the population adopt this mode of transport, the average risk of developing a cardiovascular disease for a person in this agglomeration is*	28%	30%	26%	26%
Your choice?	○	○	○	◉

C.5 Supplementary details and analyses

C.5.1 An overview: Models and estimation methods

Choosing the two presented models in this chapter was a decision preceded by a series of tested models with an increasing complexity of their specification as we moved forward in the data analysis. The aim of including this appendix is to give

a description of the followed steps and the work that we did and that could be the basis for future projects as a continuation of these analyses.

As mentioned in the data description, we had a sample of 1000 residents of Grenoble Metropolitan Area who made regular trips of distances above (792 participants) or below 3 kilometers (208 participants). The number of presented alternatives in the discrete choice scenarios depended on these reference trips. For those making trips of distances below 3 kilometers, we present 4 modes of transport: car, public transport, bicycle and walking. For those declaring distances above 3 kilometers (i.e. the case presented in the chapter), we omit the walking option because it is not very common to make regular trips for such long distances on foot.

Since the number of alternatives is different between participants depending on the distance, we decided to distinguish in the data analysis models with distances above 3 kilometers from those of distances below 3 kilometers. However, for both, we followed the same approach in the modelisation.

We actually started by testing different specifications of multinomial logit models with linear utility functions[1] (MNL_{linear}). Then, we assessed whether the two health attributes related to physical activity (i.e individual health impact) and air pollution (i.e public health impact) presented some heterogeneity in the preferences between the participants. We did this by introducing the coefficients of the health attributes as random following a normal distribution in a mixed logit model (ML_{linear}). We estimated the models MNL_{linear} and ML_{linear} based on the utility function specified in equation C.1 $\forall j \in \{$car, public transport, bicycle, walk$\}$[2]:

$$\begin{aligned} U_{nj} = \quad & ASC_j + \beta_{j,Time} Time_{n,j} + \beta_{Cost} Cost_{n,j} + \beta_A A_n \\ & + (\beta_{poll50} + \beta_{poll75} A_{75} + \beta_{poll90} A_{90}) Ppoll_{,}j \\ & + \beta_{phys} Pphys_{,}j \\ & + \beta_{age} age_n + \beta_{gender} gender_n + \beta_{status_{PT}} status_{PT,n} + \beta_{status_{cycling}} status_{cycling,n} \\ & + \beta_{status_{walk}} status_{walk,n} + \epsilon_{n,j} \end{aligned} \tag{C.1}$$

Then, we introduced the risk dimension in the model using power transformation, as explained in detail in the chapter. We do this by assessing, with multinomial (MNL_{risk}) and mixed logit models (ML_{risk}), the way health risk is perceived by the participants estimating a coefficient δ: over-estimating or under-estimating the risk

[1] We also tested some latent class models to identify groups of participants not considering one of the health attributes, not considering all the health attributes or even when considered them we suppose that they were confounded. The results do not identify clearly any significant groups with such behaviours regardless of the considered distance of the reference trip.

[2] For those declaring distances above 3km, the coefficient related to walking is null and is removed from the equation.

in their decision making[3]. Thus, models MNL_{risk} and ML_{risk} are estimated based on the utility function specified in equation C.2 $\forall j \in$ {car, public transport, bicycle, walk}:

$$\begin{aligned} U_{nj} = \quad & ASC_j + \beta_{j,Time} Time_{n,j} + beta_{Cost} Cost_{n,j} + \beta_A A_n \\ & + (\beta_{poll50} + \beta_{poll75} A_{75} + \beta_{poll90} A_{90})(p_{poll,car} - p_{poll,j})^{\delta_{poll50} + \delta_{poll75} A_{75} + \delta_{poll90} A_{90}} \\ & + \beta_{phys}(p_{phys,car} - p_{phys,j})^{\delta_{phys}} \\ & + \beta_{age} age_n + \beta_{gender} gender_n + \beta_{status_{PT}} status_{PT,n} + \beta_{status_{cycling}} status_{cycling,n} \\ & + \beta_{status_{walk}} status_{walk,n} + \epsilon_{n,j} \end{aligned} \tag{C.2}$$

C.5.2 Effect of the attributes: Estimated VOT and WTP

To facilitate the reading of the results of the different mentioned models, we choose to present only the influence of the attributes presented in the discrete choice experiment on the mobility preferences[4]. We translate these effects in terms of money by estimating the Value Of Time (VOT) and the Willingness To Pay (WTP) for health risk reductions. We estimate them following the equations C.3 and C.4 that depend of the specification of the utility function[5].

- VOT and WTP for models MNL_{linear} and ML_{linear}

$$\begin{aligned} VOT_j &= -\frac{\beta_{Timej} \times 60}{\beta_{cost}} \\ WTP_{phys} &= -\frac{\beta_{phys} \times 10}{\beta_{cost}} \\ WTP_{poll} &= -\frac{\beta_{poll} \times 10}{\beta_{cost}} \\ WTP_{poll_{75}} &= -\frac{(\beta_{poll} + \beta_{poll_{75}}) \times 10}{\beta_{cost}} \\ WTP_{poll_{90}} &= -\frac{(\beta_{poll} + \beta_{poll_{90}}) \times 10}{\beta_{cost}} \end{aligned} \tag{C.3}$$

- VOT and WTP for models MNL_{risk} and ML_{risk}

[3]The results of these last models are specifically the ones presented in the chapter only for distances above 3 kilometers

[4]The other results regarding the estimated coefficients and the effects of the socio-demographic variables could be communicated upon request.

[5]"In calculating a measure of WTP, it is important that both attributes to be used in the calculation are found to be statistically significant, otherwise no meaningful WTP measure can be established." (Hensher et al., 2005, p. 359)

$$
\begin{aligned}
VOT_j &= -\frac{\beta_{j,Time,j} \times 60}{\beta_{cost}} \\
WTP_{j,phys} &= -\frac{\delta_{phys}\beta_{phys} \times (p_{phys,car} - p_{phys,j})^{\delta_{phys}}}{\beta_{cost}} \\
WTP_{j,poll50} &= -\frac{\delta_{poll50}\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{\delta_{poll50}-1}}{\beta_{cost}} \\
WTP_{j,poll75} &= -\frac{(\delta_{poll50} + \delta_{poll75})\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{(\delta_{poll50}+\delta_{poll75})-1}}{\beta_{cost}} \\
WTP_{j,poll90} &= -\frac{(\delta_{poll50} + \delta_{poll90})\beta_{poll50} \times (p_{poll,car} - p_{poll,j})^{(\delta_{poll50}+\delta_{poll90})-1}}{\beta_{cost}}
\end{aligned}
\tag{C.4}
$$

The resulting VOT and WTP from the different models are summarized in the following tables. Table C.1 demonstrates that for distances below 3km, the time attribute influences significantly only the choice of walking with VOT ranging between 6 and 19 €/hour depending on the type of the model. VOT for car, public transport and bicycle can only be calculated for distance above 3 km. VOT for car is comprised between 4 and 6 €/hour, which is in the low range of French guideline values (Quinet et al., 2014) and literature (Wardman et al., 2012). The public transport VOT range between 7 and 8.5 €/hour, which is consistent with the French values of Wardman et al. (2012)'s meta-analysis. There are still very few studies on the value of time of active modes. However, we find VOT for cycling between 7 and 9 €/hour close to the values provided in Börjesson and Eliasson (2012) and Schmid et al. (2019).

Regarding the estimated values of WTP to reduce individual and public health risks, we calculate them in the first models MNL_{linear} and ML_{linear} for a 10% risk reduction. For distances below 3km, the participants seem to be willing to pay only for a risk reduction when there is a small share (50%) of the population already adopting an alternative mode to the car with values between 6 and 8 €/10% risk reduction. With longer distances, the participants declare lower WTP for the same risk reduction with the 50% of almost 2 €/10% risk reduction. However, they demonstrate small but significant WTP for the other types of information for instance with WTP for 10% individual risk reduction ranging between 0.75 and 0.82 €.

When considering the individual perception of risk reduction in the calculation of the WTP, we find no significant heterogeneity between the participants' preferences related to the health attributes giving almost similar values of WTP between MNL_{risk} (table C.3) and ML_{risk} (table C.4), especially with distances above 3km.

For distances below 3km, we notice that WTP for public risk reduction with a high share (90%) of the population already adopting an alternative mode to the car is not significant MNL_{risk} but becomes significant in ML_{risk}. The opposite situation occurs with WTP for individual risk reduction having a significant effect in ML_{risk} and not in MNL_{risk}. We have no clear explanation for this identified reversal other than the low number of observations for shorter distances giving less stable results than the observations with longer distances.
Regardless of the type of model and the distance, we find positive WTP for risk reduction meaning that information about the individual and public health are significant determinants of mobility choices. However, we note that even though the WTP are increasing with larger risk reductions, the function is concave and the marginal effect of an additional point of reduction is very low. Which means that the reduction itself has an impact on choices but the amount of this reduction is under-estimated.

To conclude, information about the public and individual health impacts seem to be able to modify significantly mobility practices encouraging the choice of alternatives to the car. Our results show that this is true not only for trips with long distances but also for short ones. This is interesting because a considerable share of 63% of the french workers still use the car to make short home-work trips of distances below 3km [6]. These individuals could be targeted by well-thought communication strategies around, both, information about individual and public health impact with special attention to the way they are framed.

Table C.1: Value of time for distances above and below 3km

	Below 3km				**Above 3km**			
VOT (€/hour)	**MNL linear**	**ML linear**	**MNL risk**	**ML risk**	**MNL linear**	**ML linear**	**MNL risk**	**ML risk**
Car					5.96	4.5	4.13	4.13
Public transport					8.54	7.5	6.91	6.91
Bicycle					9.08	8.03	7.31	7.31
Walk	18.8	19.59	6.63	5.73				

Grey cells = Non significant coefficients

[6] Based on the population census of 2017 done by Insee.

Table C.2: Willingness to pay for risk reduction for distances above and below 3km without considering the individual risk perception

		Below 3km		Above 3km	
WTPphys(€/10% lower risk)		**MNL linear**	**ML linear**	**MNL linear**	**ML linear**
All modes	mean			0.75	0.82
	std				-1.47
WTPpoll(€/10% lower risk)					
All modes (50% of population)	mean	6.04	8.05		1.81
	std				
All modes (75% of population)	mean				2.91
	std		-5.63		
All modes (90% of population)	mean			2.6	3.4
	std				

Notes:
Grey cells = Non significant coefficients
std= standard deviation

Table C.3: Willingness to pay (in €) for risk reduction for distances above and below 3km considering individual risk perception

			Above 3km (MNL risk)		
Risk difference	Corresponding mode	WTPphys	WTPpoll (50% of population)	WTPpoll (75% of population)	WTPpoll (90% of population)
1	Public transport		0.8	0.93	1.27
2	Public transport	0.851	0.81	0.94	1.28
3	Public transport or Bicycle		0.82	0.95	1.29
4	Public transport	0.863	0.82	0.95	1.29
5	Bicycle	0.873	0.83	0.96	1.3
6	Public transport	0.87			
10	Bicycle	0.88			
15	Bicycle	0.88			
			Below 3km (MNL risk)		
Risk difference	Corresponding mode	WTPphys	WTPpoll (50% of population)	WTPpoll (75% of population)	WTPpoll (90% of population)
1	Public transport		1.26	0.86	
2	Public transport or Bicycle	0.46	1.3	0.87	
3	All alternatives	0.46	1.32	0.88	
4	All alternatives	0.46	1.34	0.88	
5	Bicycle or Walk	0.47	1.35	0.89	
6	All alternatives	0.47			
10	Walk	0.47			

Grey cells = Non significant coefficients

Table C.4: Willingness to pay (in €) for risk reduction for distances above and below 3km considering individual risk perception and preference heterogeneity

			Above 3km (ML risk)		
Risk difference	Corresponding mode	WTPphys	WTPpoll (50% of population)	WTPpoll (75% of population)	WTPpoll (90% of population)
1	Public transport		0.79	0.93	1.27
2	Public transport	0.86	0.81	0.94	1.28
3	Public transport or Bicycle		0.82	0.95	1.29
4	Public transport	0.87	0.82	0.95	1.29
5	Bicycle	0.87	0.83	0.96	1.3
6	Public transport	0.87			
10	Bicycle	0.88			
15	Bicycle				
			Below 3km (ML risk)		
Risk difference	Corresponding mode	WTPphys	WTPpoll (50% of population)	WTPpoll (75% of population)	WTPpoll (90% of population)
1	Public transport		1.29	0.96	0.88
2	Public transport or Bicycle		1.32	0.97	0.89
3	All alternatives		1.34	0.98	0.9
4	All alternatives		1.35	0.98	0.9
5	Bicycle or Walk		1.36	0.98	0.91
6	All alternatives				
10	Walk				

Grey cells = Non significant coefficients

Appendix D

Appendices chapter 4

D.1 Justification of the choice of interventions

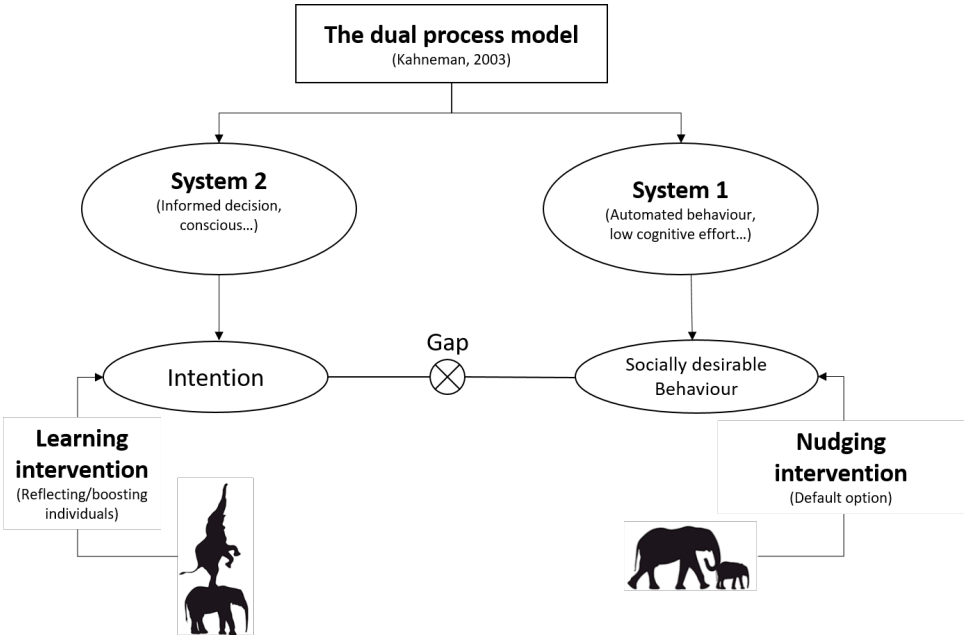


Figure D.1: Tested interventions on intentions and behaviour

Images of the elephants from a presentation by Ralph Hertwig at the German Rector's Conference.

D.2 Data collection timeline

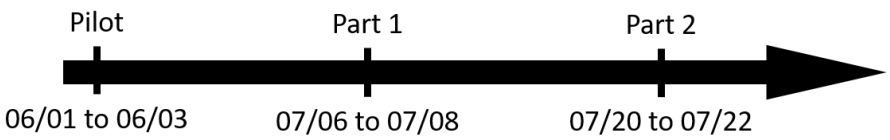


Figure D.2: The data collection timeline

D.3 Pilot experiment

D.3.1 Experimental design

Conducting a pilot experiment allowed us to improve and finalize the design of our main experiment. One of the main objectives was to investigate whether we have a gap in the context of a charity game (CG) with different giving mechanisms, so our interventions had meaning. We also wanted to verify if intentions and behaviours are stable in time. Additionally, we tested effort tasks in the realization of the behaviour and how this could iNEluence the gap (Gill and Prowse, 2019). To this end, the pilot followed a within-participants design with one treatment (see table D.1).

It took place online in early June 2021 with a sample of 48 individuals living in Grenoble metropolitan area (France). We administered it using the LimeSurvey Open Source survey tool (LimeSurvey Project Team / Carsten Schmitz, 2012) sending a participation link via e-mail. We kept the link activated for three days to collect the answers. Participating in the pilot took around 20 minutes. We iNEormed the participants, beforehand, that they will be remunerated €5 as a participation fee and that their decisions during the experiment would allow them to gain an additional maximum amount of €10. Thus, participants could gain between €5 and €15 for their participation.

This experiment was organized in four phases and at the beginning of each phase the participant gets an endowment of €10, declares his intentions to donate (Two measures of intention: A Likert scale qualitative measure and a quantitative measure of intended level of donation), chooses the charity he wants to donate to among a list of five organizations[1] then, donates. participants were instructed that, at the end of the session, only one of the four phases will be randomly drawn to determine their final gain and donation. Hence, the participant gets [€5 + €10 - amount of donation]. The defined amount of donation is actually disbursed to the chosen charity.

The four phases composing this experimental study are:

> *Phase 1: a CG with an opt-out option.* It is a classical CG where we incorporate the possibility for the participant to choose not to participate to the game -"opt-out"- and simply leave with his/her endowment.
>
> *Phase 2: a classical CG.*
>
> *Phase 3: a CG with a slider task to gain the initial endowment.* In this case, we do not give directly the initial endowment of €10 to the participant. But,

[1] Croix-Rouge Française, Téléthon, Agir pour l'environnement, Les Amis de la terre and Fondation Nicolas Hulot pour la nature et l'homme

he/she had to finish a task of moving fifty sliders from left to right to earn this amount. Once this mandatory task is done, we ask the participant his/her intention to donate, the charity he/she would like to choose and the actual amount of donation.

Phase 4: a CG with a slider task to donate. Here, the participants needed to use the proposed alterable fifty sliders to define the amount of donation. Each slider moved from left to right refers to a donation of 20 cents. If the participant wants to give €10, he/she needed to move all fifty sliders to the right.

Even though the phases are independent, we control for a possible order effect by testing three versions of our design. In version 1 we present phase 1, 2 , 3 and 4. In version 2, we present phase 1, 2, 4 and 3. And in a final version 3, we present phase 4, 3, 1 and 2.

Table D.1: Experimental design of the pilot study

Phase	Baseline
Phase 1	Intention & choice of charity Opt-out behaviour/Donation
Phase 2	Intention & choice of charity behaviour/Donation
Phase 3	Intention & choice of charity Slider task for initial endowment behaviour/Donation
Phase 4	Intention & choice of charity behaviour/Slider task to donate

D.3.2 Results

We had a sample of 48 participants (some descriptive statistics in table D.2), among which 77.08% were female. The mean age of our sample is 42 years old. Almost half of the participants had 5 years or more in higher education. Only 4% had no diploma, 17% had a baccalaureate and 31% had 2 or 3 years of higher education. Regarding the income, we had a roughly equal distribution between the different income ranges. We find a mean quantitative intention of 2.92€ (SD=3.31) and a mean donation of 3.06€ (SD=3.41) over all the phases. In phase 1, where the individuals had the opt-out option, we find 20.83% of our sample who decide to not give 'opt-out" during this phase, keep all the money, and move to the next phase.

Comparing pairs of the the declared quantitative intentions using a Wilcoxon signed-rank test (those of phase 1 against the other, those of phase 2 agains the others, etc.), we find no significant difference between them. This means that the quantitative intentions are stable between phases.
We also find high levels of correlation between these measured intentions and the related subsequent donations with significant and positive spearman correlation coefficients higher that 0.7.
None of our variations between the phases (i.e opt-out option, slider tasks, etc.) change significantly the level of intentions, nor donations. Thus, our participants show a strong internal consistency with intention and donation between the different phases, regardless of their order.
We have a non significant difference between intentions and donations. 80% of the cases present an identical level of donation to the declared intention. Even though the gap is not significant, it is the largest for phase 4 with a mean monetary gap that is equal to 1.2€, then 0.56€ for phase 1, 0.27€ for phase 3 and 0.13€ for phase 2.

At the end of this pilot, we chose phase 1 and phase 4 to use in the design of our main experiment depending on the intervention. We also decided to ask once for the choice of the charity organisation since it did not change through out the phases. Besides, we decided to introduce a more realistic larger time margin between the moment intentions are measured and donations are realized using a distraction task (Linda conjunction problem).

Table D.2: Descriptive statistics of the pilot experiment

	All phases	
Observations	*48*	
	Mean	**SD**
Age(years)	41.6	12.6
Intentions(€)	2.92	3.31
Donations(€)	3.06	3.41
	Frequency	**Proportion (%)**
Female(=1 if female)	37	77.08
Income(€)		
Less than 1000	6	12.50
1000 to 1500	9	18.75
1500 to 2000	7	14.58
2000 to 3000	9	18.75
3000 to 4000	5	10.42
4000 to 5000	3	6.25
5000 to 6000	3	6.25
More than 6000	3	6.25
No answer	3	6.25
Education		
No diploma	2	4.17
Baccalaureate	8	16.67
Bac +2/+3	15	31.25
Bac+5 or more	23	47.92
Opt-out(=1 if yes)	10	20.83

Notes: SD: Standard deviation

D.4 Instructions of the main experiment

The instructions are translated from French to English.

D.4.1 Learning intentions intervention (Int1quali&quanti)

Learning about the charities through questions [2]

Answer these questions about the charities listed.
Please tell us which organization...

[2]The presentation of the questions was randomized and x is the correct answer.

Table D.3: Quiz about the presented charities

	Croix-Rouge Française	Téléthon	Agir pour l'environnement
Which organization has 27 teams accompanying 200 people with Alzheimer's disease and 21 Parent-Child Spaces that have welcomed 1,200 families and distributed thousands of packages?	x		
Which organization is in charge of iNEormation campaigns for children and has created the campaign: marcreauvert so that children can discover nature?			x
Which organization is fighting for the regulation and evaluation of nanoparticles in our daily lives? (Nanoparticles are 10,000 times smaller than a grain of salt, these extremely small particles have new properties that are as powerful as they are uncontrolled)			x
Which organization has 204 mobile teams that have made more than 277,000 encounters with homeless people during outreach and distributed 100,000 hygiene kits?	x		
Which organization is lobbying against the reauthorization order of the neonicotinoid insecticides family at the State Council with the help of their lawyer?			x
What organization launches a major fundraiser for medical research during 30 hours of live television?		x	
Which organization donated 89 million euros to the French Muscular Dystrophy Association in 2013?		x	
What organization helps families and individuals after a natural disaster, such as the recent hurricane IRMA in Saint Martin?	x		
Which organization divides the money raised between funding research into genetic diseases and supporting patients and their families?		x	

Reflecting about the charities

The list of organizations from which you will be able to choose all defend causes for the improvement of the health, social and environmental situation. These are, along with economic development, the main issues of sustainable development.
Sustainable development is presented as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", quote from Mrs. Gro Harlem Brundtland (1987).
More specifically, and according to the United Nations (UN), the Sustainable Development Goals are a call to action for all countries - poor, rich and middle-income - to promote prosperity while protecting the planet.
They recognize that ending poverty must go hand in hand with strategies that expand economic growth and address a range of social needs, including education, health, social protection and employment opportunities, while combating climate change and protecting the environment.
https://www.un.org/sustainabledevelopment/fr/

We would like to know your opinion on this participant by answering the following question.

Please answer this question by writing a short paragraph (between 2 and 10 lines).

Tell us which organization you prefer, why and how you think it will help shape a better world for future generations?

D.4.2 Default option intervention (don1)

To make the donation, you need to drag sliders. For each slider you place on the right, you give 20 cents to the charity from your initial endowment of €10. You can therefore position a maximum of 50 sliders, which represents a total donation of €10.
If you don't want to donate, all the sliders must be set to the left.
If you wish to donate the €10, all the sliders must be positioned on the right.
If you want to donate another amount, the number of sliders on the right must be equal to this amount (Number of sliders x 20 cents = donation amount).
Currently all the sliders are positioned to the right. If you click on "Next", €10 are automatically given to the charity.
To donate an amount other than €10, drag the necessary number of sliders with the mouse (the donation amount is displayed at the bottom).

Figure D.3: Example sliders for the first donation in the default option treatment

D.5 Measurement of the psychological variables

Additionally to measuring emotions using the Positive and Negative Affect Scale (Watson et al., 1988), we measure the attitudes to charities and donations (Gaudeul and Kaczmarek, 2017) using five items asking the participants about their opinions regarding the work done by the chosen charity and the way it handled charity money (eg. "I think that the work done by the charity is important") on a seven-point Likert scale measure (1=totally disagree to 7=totally agree). We also measure the susceptibility of being iNEluenced by commitment by translating to french the six items regarding this type of iNEluentiability previously presented by Kaptein et al. (2012). Besides, we present a classical cognitive reflection test CRT (Frederick, 2005) with three questions. Table D.4 includes the items used to measure these variables.

Table D.4: List of items measuring the psychological variables

Variable	Adapted from	Item	Scale
Emotion	Watson et al. (1988)	Indicate on the following scale how well each adjective describes your current emotional state:	1. Strongly disagree to 5. Strongly agree.
		Proud, Enthusiastic, Inspired, Determined, Active, Serene, CoNFident, Guilty, Ashamed, Upset, Anxious, Distrustful, Angry, Betrayed	
Susceptibilty to be iNEluenced by commitment	Kaptein et al. (2012)	As you read the following statements, tell us whether you 1. "strongly disagree" to 7. "strongly agree"	1. Strongly disagree to 7. Strongly agree.
		Whenever I commit to an appointment I always follow through.	
		I try to do everything I have promised to do.	
		When I make plans I commit to them by writing them down.	
		Telling friends about my future plans helps me to carry them out.	
		Once I have committed to do something I will surely do it.	
		If I miss an appointment, I always make it up.	
Attitude to charity	Gaudeul and Kaczmarek (2017)	Tell us if you agree 1. "strongly disagree" to 7. "strongly agree" with the following statements using your chosen charity as a reference.	1. Strongly disagree to 7. Strongly agree.
		I think the work of the charity is important	
		I am interested in the work of the charity	
		I think the charity is wasting its money	
		I wish there were more charities like the one I chose	
		I think the charity makes a small contribution to the cause	
Cognitive Reflection Test	Frederick (2005)	Please answer the following questions	score = +1 if correct answer
		A baguette and a candy cost 1.10 € in total. The baguette costs 1.00 € more than the candy. How much does the candy cost? (in €)	
		If it takes 5 machines 5 minutes to create 5 objects, how long would it take 100 machines to create 100 objects? (in minutes)	
		In a lake, there is a lotus. Every day the lotus doubles in size. If it takes 48 days for the lotus to cover the whole lake, how long would it take for the lotus to cover half the lake? (in days)	

D.6 Supplementary statistics

D.6.1 Randomisation check

Table D.5: Donation and randomised checks

Don1	Coef.	SE	t	p-value
age	0.011	0.018	0.58	0.566
female	-0.333	0.416	-0.80	0.424
constant	4.108	0.795	5.17	0.000

Note: Simple linear regression on the first donation to show that age and female have no significant impact.
SE: Standard Errors

D.6.2 Descriptive statistics of the intentions and donations

We find a mean intended donation of €4.5 for the first measure and €4.18 for the second measure, that took place two weeks after the first. These quantitative intentions are comparable to a first mean actual donation of €4.36 and €4.15 for the second donation that both took place in the second part of the experiment. Regarding the qualitative intentions, the majority of our sample are more or less willing to give a positive donation during the experiment with a mean int1quali equal to 4.83 points and a mean int2quali equal to 4.68 points[3]. Comparing these intentions to the binary variables donate1 and donate2, we find that 81% of the sample give a positive donation when asking them to donate the first time (donate1). This share decreases slightly to 77.24% when asking for a second donation (donate2).

Table D.6: Descriptive statistics of the variables of intentions and donations

	All		**Baseline**		**Default**		**Learning**	
Observations	*312*		*106*		*93*		*113*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Int1quanti (€)	4.50	3.68	3.66	3.34	4.66	3.61	5.15	3.92
Int2quanti (€)	4.18	3.63	3.64	3.28	4.73	3.71	4.22	3.84
Don1 (€)	4.36	3.67	3.86	3.45	4.96	3.79	4.33	3.71
Don2 (€)	4.15	3.66	3.70	3.55	4.60	3.69	4.19	3.72
Int1quali	4.83	1.75	4.80	1.77	4.79	1.72	4.89	1.77
Int2quali	4.68	2.01	4.52	2.00	4.98	1.88	4.57	2.10
	Frequency	Proportion	Frequency	Proportion	Frequency	Proportion	Frequency	Proportion
Donate1 (=1 if don1>0)	252	80.77	85	80.19	75	80.65	92	81.77
Donate2 (=1 if don2>0)	241	77.24	79	74.53	74	79.57	88	77.88

Note: SD: Standard deviation

[3]For int1quali, we have 53.21% of our sample who declare that they more or less agree, agree or strongly agree with the sentence "I intend to make a donation during the experiment". For int2quali, we have 58.34% of the sample who declare that they more or less agree, agree or strongly agree with the same sentence.

D.6.3 Spearman's correlation coefficients matrices

Table D.7: Matrices of Spearman's correlation coefficients between intentions and donations for the baseline treatment

	int1quali	int2quali	donate1	donate2
int1quali	1			
int2quali	0.77*	1		
donate1	0.55*	0.63*	1	
donate2	0.43*	0.62*	0.85*	1

	int1quanti	int2quati	don1	don2
int1quanti	1			
int2quanti	0.87*	1		
don1	0.85*	0.93*	1	
don2	0.80*	0.88*	0.95*	1

Notes: * for at least 5% significant level.
Int1quali and Int2quali: qualitative measures of intentions.
Int1quanti and Int2quanti: quantitative measures of intentions.
Don1 and Don2: level of donation between 0 and €10.
Donate1 and Donate2: = 1 if the participant indicated a donation level different than 0€.

D.6.4 Treatments' effects on emotions

Table D.8: Comparison of the positive and negative emotions between treatments

Z-value	Baseline	learning	Default
PE1 vs NE1	8.62***	7.72***	8.61***
PE2 vs NE2	8.63***	7.32***	8.78***

Notes: Test statistics of the Wilcoxon signed-rank test
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table D.9: Comparing each measured emotion between treatments

Z-value	PE1	NE1	PE2	NE2	Emo1	Emo2
Default vs Baseline	0.777	0.112	1.538	-0.014	0.590	1.283
Learning vs Baseline	-1.095	0.459	-1.199	1.092	-0.904	-0.881
Learning vs Default	-1.702	0.229	-2.235**	0.891	-1.265	-2.004**

Notes: Test statistics of the Mann Whitney tests
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$
Emo1=PE1-NE1, Emo2=PE2-NE2

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French summary

Depuis la seconde moitié du XXe siècle, l'humanité vit dans une croissance rapide et continue connue sous le nom de la "Grande Accélération" (Steffen et al., 2015). Elle se caractérise par une urbanisation persistante : en 2021, 75% de la population européenne vivent dans des zones urbaines (Statista, 2022) et cette part pourrait atteindre 84% en 2050[4]. La hausse des prix de l'immobilier et des loyers dans les centres urbains (Charlton, 2021) combinée à des transports de plus en plus performants et s'appuyant sur des carburants peu coûteux (Ostermeijer et al., 2022; Christiansen and Loftsgarden, 2011) ont conduit à un fort étalement urbain. Les ménages se sont alors massivement installés dans les banlieues où les logements sont plus abordables (Clark et al., 2018). Cette situation a impacté les pratiques de mobilité, les individus comptant davantage sur la voiture privée pour se déplacer et accéder aux commodités les plus éloignées (Ostermeijer et al., 2022). Cette dépendance au véhicule privé est très élevée en France : en 2019, indépendamment du motif du déplacement, 81% de la population utilisent la voiture avec un parc automobile constitué de 60% de véhicules roulant au diesel (Babet et al., 2021).

Le trafic routier est associé à de nombreuses externalités négatives : congestion et accidents de la circulation, pollution de l'air, émissions de gaz à effet de serre, bruit et vibrations, pollution du sol et de l'eau, modification du paysage éco-urbain, etc. (Pîrlea and Burlacu, 2014). Le secteur routier est ainsi le premier contributeur aux émissions de NOx en France avec 56% des émissions totales en 2019 (dont 49% sont causées par les véhicules privés) et il est responsable de 17% des émissions totales de PM2,5. Ces polluants émis endommagent notamment le sol, l'eau, la végétation et l'air.

L'exposition importante de la population dans les zones urbaines à des concentrations élevées de polluants constitue non seulement un enjeu environnemental mais aussi un enjeu sanitaire. Ces polluants augmentent le risque de maladies respiratoires et cardiovasculaires (EPA, 2021a; Citepa, 2020b) et provoquent des décès prématurés (Anses, 2019). En 2019, l'Union Européenne (UE) a comptabilisé 307.000 décès prématurés attribués à une exposition prolongée aux particules fines

[4]https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation_en

(EEA, 2021c). 178.000 de ces décès prématurés auraient pu être évités si tous les membres de l'UE avaient respecté les seuils maximums de concentrations recommandés par l'Organisation Mondiale de la Santé (EEA, 2022c). Ces conséquences environnementales et sanitaires se traduisent par des pertes économiques importantes. Le rapport de van Essen et al. (2018) montre que la pollution atmosphérique causée par le transport routier a coûté pour l'UE en 2016 entre 67 et 80 milliards d'euros. Les études soulignent le rôle des changements de mobilité individuelle vers la mobilité active (transport en commun, vélo ou marche) et les politiques des villes pour réduire ces coûts (WHO, 2021; Delft, 2020).

Au-delà de ces externalités, encourager la mobilité active réduit la sédentarité qui caractérise aujourd'hui la vie dans les pays industrialisés. L'OMS considère la sédentarité comme étant le deuxième principal facteur de risque responsable de la dégradation de la santé dans ces pays (WHO, 2002b). Ainsi, choisir un mode actif est une approche innovante pour intégrer l'activité physique dans la vie quotidienne des individus (Dons et al., 2015). Bouscasse et al. (2022a) montrent que le report modal vers la mobilité active pourrait même générer un effet bénéfique sur la santé supérieure à celui de la réduction de la pollution atmosphérique.

Tous ces éléments suggèrent que les efforts individuels et de la puissance publique doivent viser la réduction des impacts environnementaux, sanitaires et économiques du trafic routier. Les pratiques individuelles actuelles de mobilité doivent se reporter vers les mobilités actives et les autorités publiques doivent faciliter ce report en appliquant des mesures incitatives.

Pour encourager le changement des pratiques actuelles de mobilité, il est essentiel de mieux comprendre les déterminants individuels afin d'identifier les leviers les plus efficaces. Cependant, l'étude de ce comportement est complexe car un choix modal est le résultat de la combinaison de multiples déterminants de nature différentes mais interdépendants (De Witte et al., 2013). La méta-analyse de Javaid et al. (2020), présentant une revue de 75 revues de psychologie, d'économie, de sociologie et d'urbanisme, classe ces déterminants en trois catégories principales: 1) les facteurs individuels matériels et psychologiques tels que les attitudes, les croyances et les habitudes ; 2) les facteurs sociaux tels que l'influence sociale ou les normes subjectives ; 3) les facteurs liés aux infrastructures tels que la densité ou la qualité du système de transport, y compris les coûts en temps et économiques. Cette revue permet d'identifier comme facteur individuel clé du report modal les habitudes et les croyances sur le contrôle perçu. Pour ce qui relève des facteurs sociaux, la probabilité qu'un individu modifie ses pratiques de mobilité augmenterait dans le cas où son entourage adopte des modes actifs. Enfin, les déterminants les plus influant du report modal dans le domaine des infrastructures sont l'existence

de pistes cyclables, de zones piétonnes, d'un système de transport accessible ou de courtes distances de déplacement. La revue de littérature souligne néanmoins qu'il est nécessaire de chercher à mieux appréhender les effets de certains déterminants individuels ou sociaux sur le report modal.

Une part importante des études s'intéressant aux déterminants de la mobilité et du report modal s'appuie sur la théorie du comportement planifié (Theory of Planned Behaviour TPB, Ajzen, 1991). Selon cette théorie, les intentions sont les antécédents les plus proches du comportement. Ces intentions sont définies comme la quantité d'effort que la personne est prête à fournir pour adopter le comportement. Étant donné que le report modal vers la mobilité active peut être considéré à la fois comme un comportement pro-environnemental et comme un moyen de pratiquer une activité physique, des perspectives théoriques plus larges doivent être envisagées pour comprendre la motivation qui explique ce comportement. Par exemple, la théorie de l'autodétermination (Self-Determination Theory SDT, Deci and Ryan, 1980) fournit un cadre théorique largement utilisé pour étudier les motivations derrière l'adoption de pratiques plus saines (comme l'activité physique). Ainsi, la SDT est applicable à l'étude de la mobilité active. Elle définit un continuum de motivations allant de la motivation autodéterminé provenant de facteurs internes d'intérêt, de plaisir ou de satisfaction à la motivation non autodéterminé provenant généralement de motivations externes distinctes du comportement lui-même, comme un sentiment de pression sociale de culpabilité ou de honte. L'utilisation d'une telle théorie dans les études sur les transports apporterait une nouvelle perspective à cette discipline dans l'explication des déterminants motivant le report modal.

Selon Javaid et al. (2020), les disciplines diffèrent dans leur compréhension du comportement de mobilité. Bien qu'aucune de ces perspectives ne prétende à l'exhaustivité ou à l'exclusivité, et en raison des frontières disciplinaires, ces différentes perspectives finissent par examiner les pièces d'un puzzle plutôt que de fournir une image complète. Ainsi, des collaborations entre disciplines sont nécessaires pour mieux comprendre les déterminants de la mobilité. Les quelques études multidisciplinaires existantes (eg. Koszowski et al., 2019; Sallis et al., 2004) confirment l'utilité de ces collaborations pour formuler des recommandations de politiques publiques cohérentes entre les disciplines, ce qui garantirait une gouvernance politique avec des objectifs alignés.

Cette thèse contribue, par le biais d'approches de théories économiques et psychologiques, à une meilleure compréhension des déterminants individuels pour l'adoption de comportements pro-sociaux et pro-environnementaux. En se focalisant sur les pratiques individuelles de mobilité, nous tentons d'identifier des leviers de politiques publiques pour promouvoir la mobilité active. L'étude de ce comportement est par-

ticulièrement importante compte tenu de ses externalités environnementales et sanitaires précédemment soulignées. Par conséquent, la question centrale de cette thèse est la suivante : *Comment peuvent être utilisées les connaissances comportementales pour identifier les leviers de politique publique afin de promouvoir l'adoption de la mobilité active et, plus généralement, les comportements pro-sociaux ou pro-environnementaux?*

Le premier chapitre évalue l'acceptabilité du projet de mise en place des Zones à Faibles Emissions (ZFE) restreignant la circulation des voitures les plus polluantes. Le deuxième chapitre, basé sur le cadre de la SDT, met l'accent sur la relation motivation-intention de report modal et étudie le rôle des habitudes de mobilité active dans cette relation. Dans le troisième chapitre, basé sur une expérience de choix discret, l'objectif est de tester l'influence de la présentation d'informations sur les risques de morbidité liés aux pratiques de mobilité sur les intentions de report modal. En adoptant une perspective plus large que l'étude du report modal, le quatrième chapitre teste des interventions publiques applicables non seulement au domaine des transports mais adaptées à tout autre comportement pro-social ou pro-environnemental. Pour l'ensemble de la thèse, la Métropole de Grenoble constitue le terrain d'étude avec la réalisation de deux enquêtes et une expérience de laboratoire en ligne. Notre intérêt à expliquer principalement les intentions de report modal plutôt que le comportement réel est d'abord justifié par la difficulté de capturer le comportement réel en matière de transport par des enquêtes déclaratives. Ensuite, il est motivé par l'utilisation générale de la mesure des intentions dans des études antérieures sur la mobilité individuelle, rendant ce travail comparable à cette littérature. Cependant, nous tentons de nous rapprocher de la mesure des comportements pro-sociaux ou pro-environnementaux réels à travers l'expérience de laboratoire mise en oeuvre dans le dernier chapitre de cette thèse.

Chapter 1

Afin d'améliorer la qualité de l'air, les autorités publiques ont mis en place des mesures d'amélioration de la qualité de l'air telles que les ZFE restreignant l'accès des véhicules les plus polluants aux centres urbains caractérisés par une forte exposition de la population à la pollution. L'instauration de ZFE est devenue obligatoire dans les zones urbaines présentant des seuils de concentration de polluants et d'exposition dépassant les valeurs limites. Il s'agit de La loi Climat et Résilience qui prévoit la mise en place de ZFE dans les agglomérations de plus de 150 000 habitants d'ici fin 2024.

L'introduction de mesures publiques visant à créer un report modal vers la mobilité active pourrait avoir des conséquences non seulement sur la mobilité des indi-

vidus mais aussi sur leurs activités quotidiennes. Cependant, rares sont les études qui évaluent l'acceptabilité par le public d'une mesure ZFE avant de l'introduire. En effet, l'acceptabilité est un élément essentiel pour garantir le succès d'une mesure publique. Cette idée a été confirmée dans des études antérieures (Gu et al., 2018; Jagers et al., 2017; Rye and Ison, 2005) qui ont évalué l'acceptabilité d'autres mesures d'amélioration de la qualité de l'air (eg. Politiques de congestion, politiques de tarification). En France, les études existantes sur les ZFE sont principalement menées à Paris estimant les impacts environnementaux et sanitaires en se basant sur des scenarios hypothétiques mettant moins l'accent sur l'analyse de l'acceptabilité de cette mesure (eg. Poulhès and Proulhac, 2021; Host et al., 2020).

Nous contribuons à travers ce chapitre à enrichir cette littérature en prenant comme cas d'étude le projet de mise en place de ZFE à Grenoble. Nous tentons de répondre à la question suivante : Quels sont les déterminants de l'acceptabilité des habitants de la métropole grenobloise à la ZFE comme mesure d'amélioration de la qualité de l'air ? Ce type d'évaluation permet aux autorités publiques de mieux étudier la faisabilité de la mesure, de connaître les attentes de la population ciblée, les éventuels obstacles à l'adoption du comportement encouragé et, par conséquent, d'adapter les politiques d'accompagnement prévues pour garantir une plus grande efficacité économique et sociale. Ainsi, l'objectif de ce chapitre était de présenter une évaluation ex-ante (i.e. avant l'introduction de la mesure) de l'acceptabilité de la ZFE à Grenoble afin d'aider les autorités locales (La Metro) à mettre en oeuvre efficacement cette mesure.

Pour répondre à cette question de recherche, nous évaluons et expliquons l'acceptabilité d'un échantillon de 1.304 résidents de Grenoble à l'aide de données collectées par une enquête téléphonique en 2019. Nous utilisons des statistiques inférentielles et une régression logit binaire sur les données redressées pour comparer les caractéristiques des supporters par rapport aux opposants déterminant leurs niveaux d'acceptabilité. Les déterminants de l'acceptabilité sont organisés en trois catégories : 1) les facteurs sociodémographiques comme le sexe ou l'âge, 2) les caractéristiques liées au voyage comme la vignette Crit'Air possédée et 3) les facteurs psychologiques comme les attitudes et les perceptions.

Les résultats montrent que la mise en place de la ZFE présente une acceptabilité relativement élevée avec 54% de supporters, 28% d'opposants et 17% de neutres ou d'indécis. Les analyses comparant les caractéristiques des supporters à celles des opposants montrent une faible influence des déterminants sociodémographiques sur l'acceptabilité. Les caractéristiques liées aux déplacements semblent avoir plus d'influence, avec une acceptabilité plus faible exprimée par ceux qui ont des véhicules plus polluants et des habitudes de mobilité active plus faibles. Cependant, les variables les plus déterminantes de l'acceptabilité semblent être les attitudes et

les perceptions individuelles. En fait, les participants qui sont plus préoccupés par l'environnement et qui ont des attitudes et des perceptions positives de cette mesure expriment une plus grande acceptabilité pour sa mise en oeuvre. Nous constatons un fort potentiel de report modal vers la mobilité active exprimé par nos participants dans le cas où cette mesure est mise en place, notamment pour les déplacements domicile-travail. En outre, en présentant des suggestions de mesures d'accompagnement pour augmenter l'acceptabilité des ZFE, les participants encouragent fortement l'amélioration des services de transport public en termes d'accessibilité économique, physique et sociale.

Chapter 2

Dans le deuxième chapitre, l'intention est définie comme étant l'expression de la quantité d'effort qu'une personne est prête à fournir pour adopter un comportement socialement désirable. Cet effort dépend de la motivation individuelle qui est différente d'un individu à l'autre (Thøgersen, 2005). Ainsi, l'étude de la relation motivation-intention est essentielle pour proposer des mesures qui permettent efficacement le report modal (Thiermann and Sheate, 2020). Pour étudier les motivations qui sous-tendent l'adoption de la mobilité active, nous mobilisons la théorie de l'autodétermination qui nous semble pertinente dans ce contexte. Des études antérieures ont démontré par le biais de cette théorie la relation significative entre la motivation et les intentions (eg. Hagger and Chatzisarantis, 2009) mais pas dans le cadre d'études sur la mobilité. Nous introduisons également les habitudes dans cette relation intention-motivation du fait de son impact sur les pratiques de mobilité actuelles et intentions de report modal (Eriksson et al., 2008).

En considérant le choix d'alternatives à la voiture comme un moyen de réduire les émissions de polluants et de pratiquer une activité physique, nous contribuons à cette littérature en étudiant la relation motivation-intention ainsi que du rôle des habitudes de mobilité active dans cette relation. Nous essayons de répondre à la question suivante : Quel est le rôle des habitudes de mobilité active dans la relation des motivations autodéterminées et non-autodéterminées avec les intentions de report modal?

Pour répondre à cette question, nous construisons et testons un processus motivationnel hypothétique des intentions du report modal en s'appuyant sur la SDT. L'analyse de médiation utilisant la modélisation des équations structurelles montre que la motivation autodéterminée (i.e. sentiment de plaisir, croyance dans l'utilité et de l'importance du report modal) est positivement corrélée avec des habitudes de mobilité active plus élevées et des intentions de report modal. L'effet de ce type de motivation sur les intentions en considérant les habitudes n'est qu'indirect

confirmant la forte influence des habitudes de mobilité sur le changement de comportement. Au contraire, la motivation non-autodéterminée (i.e. pression sociale, peur d'être critiqué ou jugé) est négativement corrélée aux habitudes de mobilité active et n'influence pas significativement les intentions de report modal.

Ces résultats indiquent aux autorités publiques l'importance de prendre en compte les habitudes dans la conception des interventions de changement de comportement. Le fort effet identifié des habitudes suggère la nécessité de trouver des moyens de perturber les habitudes non désirées et de favoriser la construction d'habitudes du comportement souhaité (ici, la mobilité active). Ce travail a permis d'avoir plus de clarté sur la manière dont les habitudes désirables sont influencées par les motivations. Dans le cas de la mobilité active, elles sont fortement liées aux convictions et attitudes internes de l'individu alors qu'une pression externe (sociale ou institutionnelle) de l'environnement de l'individu pourrait jouer un rôle contreproductif. Dans ce cas, des mesures publiques spécifiques permettant par exemple à l'individu de se sentir plus maître de ses décisions et d'avoir un meilleur contrôle comportemental perçu seraient plus efficaces que celles basées sur la mise en évidence des normes sociales.

Chapter 3

Dans ce chapitre, nous nous concentrons sur l'étude de l'influence de la perception des risques sanitaires sur les intentions de report modal vers la mobilité active. La mobilité active génère deux types de co-bénéfices pour la santé. Premièrement, il y a une réduction des risques sanitaires publiques liés à l'amélioration de la qualité de l'air. Deuxièmement, il y a une réduction des risques sanitaires individuels associés à l'augmentation de l'activité physique à travers la mobilité active.

Dans la littérature, rares sont les études qui ont évalué l'impact de fournir des informations sur ces risques sanitaires comme levier pour générer un report modal (Meloni et al., 2013; Sottile et al., 2015b), et à notre connaissance, aucune étude antérieure n'a évalué les conséquences de fournir ce type d'information en séparant l'impact sanitaire individuel de celui sur la population générale. Nous répondons à la question suivante : L'impact des modes de transport sur la santé est-il un déterminant individuel du choix du mode de transport ?

Nous nous appuyons pour cela sur une enquête en ligne de préférences déclarées (une expérience à choix discret, DCE) en 2019 auprès d'un échantillon final de 792 résidents de la métropole grenobloise. La DCE offrait la possibilité de choisir un mode parmi trois alternatives (voiture, transports publics et vélo) en tenant compte des déterminants classiques (temps de trajet et coût) et des déterminants sanitaires (risques sanitaires individuels et publics).

L'une des originalités de notre DCE, est de s'appuyer sur des résultats sanitaires quantifiés. Le premier risque sanitaire fait référence au risque de développer des maladies cardiovasculaires en fonction de l'exposition à la pollution atmosphérique induite par le choix du mode de transport. Le second risque est celui de développer une maladie cardiovasculaire en fonction de l'activité physique induite par le choix du mode actif. En raison du manque de familiarité des individus avec ces attributs sanitaires, nous facilitons leur compréhension en s'inspirant de la littérature médicale (Fagerlin et al., 2011) par des pictogrammes. De plus, nous indiquons des informations supplémentaires sur la part de la population qui adopte déjà un mode actif (50%, 75% et 90%) pour tester l'existence d'un effet de conformité sur les intentions de report modal.

Nous modélisons l'utilité associée à chaque mode de transport dans le cadre du modèle de choix discret (McFadden, 1974) comprenant un vecteur de variables individuelles et un vecteur de variables spécifiques à l'alternative. En ce qui concerne la façon dont nous introduisons la dimension risquée dans le modèle de choix discret, nous considérons que le répondant traite les probabilités comme la différence entre la probabilité de morbidité associé au choix de la voiture et la probabilité de morbidité associé à l'alternative. Ces probabilités pouvant être perçues différemment par les individus, nous les définissons comme une fonction puissance (Yaari, 1987; Bouscasse and de Lapparent, 2020).

Les résultats des modèles logit multinomial et mixte montrent que les informations sur les risques sanitaires individuels et publics influencent significativement les préférences des participants. Cela signifie que pour les deux informations, plus la réduction du risque de maladies cardiovasculaires est élevée, plus la probabilité de choisir un mode actif est grande. Nous identifions également un effet de conformité qui se traduit par un effet plus significatif de l'information sur le risque public que de l'effet du risque individuel lorsqu'une part plus importante (75% et 90%) de la population adopte déjà un mode alternatif. Cependant, lors de la communication de ces informations sanitaires, le simple fait de mentionner la possibilité de réduire les risques pour la santé semble avoir plus d'influence sur les préférences de mobilité que le fait d'insister sur le taux exact de cette réduction.

Ces résultats indiquent aux autorités publiques l'utilité de construire des compagnes de communication présentant les impacts sanitaires individuels et publiques pour encourager le report modal. L'information communiquée doit être accessible et notre travail permet d'identifier qu'une simple présentation d'une potentielle réduction du risque sanitaire suffit pour créer du changement comportemental.

Chapter 4

Le quatrième et dernier chapitre prend du recul par rapport aux questions liées au report modal. Il traite plus généralement du comportement pro-social ou pro-environnemental. Nous considérons que l'adoption de ces comportements est limitée par soit des intentions réelles faibles soit, le fait que, même en ayant des intentions fortes, l'on rencontre des difficultés à traduire ces intentions en comportement réel, ce qui entraîne un écart entre les intentions et les comportements. En conséquence, si nous voulons encourager l'adoption de comportements socialement désirables, nous devons soit 1) renforcer les intentions afin d'augmenter la probabilité que le comportement soit adopté, soit 2) influencer directement le comportement en essayant de réduire l'écart entre intention et comportement.

Les interventions existantes reposent principalement sur des nudges impactant le comportement en exploitant les biais cognitifs (eg. Ghesla et al., 2019). Ces interventions cherchent moins à influencer les intentions. Comme les intentions ne sont généralement pas mesurées au préalable, l'effet réel du nudge sur l'écart entre les intentions et les comportements est en général non connu. Les quelques applications du nugde sur les intentions ne parviennent généralement pas à encourager de manière significative l'adoption du comportement désirable (eg. Gaudeul and Kaczmarek, 2017). Nous pensons qu'une justification valable de cet échec est de négliger le processus derrière la formation des intentions et du comportement et comment l'intervention doit s'adapter à leurs caractéristiques respectives. En considérant le processus de raisonnement humain de Kahneman (2003), le comportement et ses intentions d'origine sont les résultats de deux systèmes de raisonnement distincts : les intentions proviennent de l'activation du Système 2 puisqu'elles sont le résultat d'un processus de pensée conscient et délibéré. Cela signifie qu'une intervention qui influence effectivement ce processus pourrait être efficace. Alors que le comportement est une manifestation d'un raccourci cognitif avec un processus de pensée rapide et subconscient activé par le Système 1. Ainsi, une intervention exploitant ce processus plus rapide serait plus adaptée.

L'objectif de ces deux interventions est d'améliorer le bien-être social. Cependant, il est essentiel de considérer le bien-être et le ressenti de l'individu pour garantir une meilleure acceptabilité de l'intervention et, par conséquent, son succès. Dans la littérature, rares sont les études qui évaluent l'impact des intervenions testés sur les émotions des participants. Thunström (2019) est l'une des rares qui a considéré qu'une intervention nudge d'étiquetage de menu peut générer un coût émotionnel, appelé aussi "taxe émotionnelle".

A notre connaissance, aucun travail antérieur n'a jamais comparé des interventions jouant sur un comportement ou une intention dans un même contexte avec

comme objectifs d'évaluer leurs effets sur l'adoption de comportement socialement désirable et leurs impact sur les émotions. Tous ces éléments amènent à la question : Afin de favoriser l'adoption d'un comportement socialement désirable, doit-on influencer les intentions par l'effort cognitif (Système 2) ou le comportement par les biais cognitifs (Système 1)?

Nous répondons à cette question en menant une expérience de laboratoire en ligne suivant un design between-within avec un jeu de charité (Eckel and Grossman, 1996). Le jeu consistait à ce que les participants décident deux fois du montant de leur don à une association caritative, entre 0 et 10 euros, avec à chaque fois une dotation initiale de 10 euros. Le paiement final des participants est le montant restant d'un don choisi aléatoirement parmi les deux dons définis précédemment ainsi qu'une indemnisation de participation fixe de 5 euros. L'échantillon final comprenait 312 résidents de Grenoble recrutés en utilisant la base de contacts interne du laboratoire GAEL. Ces participants sont répartis entre deux groupe de traitement et un groupe témoin : 106 dans le groupe témoin, 113 dans le traitement d'apprentissage et 93 dans le traitement de nudge par défaut.

Cette expérience nous a permis de mesurer deux fois les intentions et les dons, en introduisant l'intervention sur la première mesure et en évaluant son effet à long terme sur la seconde mesure. Nous avons tenté de renforcer les intentions de don en appliquant une tâche d'effort cognitif sur cette mesure, appelée intervention d'apprentissage. Elle consistait à présenter des informations supplémentaires sur les organisations caritatives proposées, à tester ces informations au moyen d'un quiz et à donner aux sujets le temps d'exprimer leur opinion sur les activités des organisations caritatives et sur l'utilité de leurs dons. La deuxième intervention est l'intervention nudge avec option par défaut qui joue sur le biais du statu quo pour influencer le comportement de don. Nous présentons aux sujets la possibilité de faire un don maximum de 10 euros en réalisant une tâche de curseur avec une option par défaut. L'option par défaut consiste à présenter 50 curseurs, chacun équivalent à 20 centimes, initialement positionnés à droite. Si le sujet ne glisse pas vers la gauche le nombre de curseurs équivalant au montant du don souhaité, un don de 10 euros est automatiquement fait.

En partant de l'hypothèse que nous pourrions être soit dans un cas d'écart entre les intentions et les dons, soit dans un cas d'absence d'écart, nous comparons les intentions, les dons et les effets des interventions par rapport au groupe témoin. Nous mesurons également l'influence des interventions sur les émotions des participants. Les résultats montrent l'utilité des deux interventions avec des effets positifs sur les intentions et les dons. Mais l'effet à court terme suggère que des améliorations devraient être entreprises pour garantir un effet positif à long terme. L'intervention d'apprentissage a effectivement confirmé que le renforcement des intentions à court

terme fonctionne, mais il n'a pas été possible de faire durer cet effet à long terme. Ainsi, l'augmentation des intentions de faire des dons ne s'est pas traduite par une augmentation réelle des dons. Par contre, l'intervention du nudge par défaut a eu un effet comportemental significatif, mais étonnamment faible par rapport à la littérature, sur l'augmentation des dons et un effet significatif sur le niveau d'attrition ce qui a entraîné un effet de sélection. En ce qui concerne les effets des deux interventions sur les émotions, nous constatons que les émotions négatives diminuent de manière significative entre les deux moments de mesure (avant et après le don), ce qui suggère une sorte d'effet de satisfaction appelé "warm glow effect". Cependant, en comparant cet effet entre les traitements, nous avons constaté qu'après le don, les émotions positives sont davantage exprimées dans le cadre du traitement d'apprentissage que le traitement nudge par défaut.

Ces résultats contribuent à enrichir la littérature sur les interventions comportementales, ce qui donne des indications intéressantes pour les autorités publiques dans la mise en place d'interventions publiques. Nous confirmons en fait la difficulté d'influencer les intentions individuelles comme véritable enjeu pour générer un changement comportemental. Les résultats concernant l'effet de ces interventions sur les émotions pourraient également être exploités pour maintenir les effets positifs des interventions. Le fait que le don maintienne les émotions positives et réduise les émotions négatives pourrait être utilisé comme une incitation supplémentaire pour encourager l'adoption de comportements socialement désirables. Les autorités publiques pourraient utiliser cet effet positif sur le bien-être individuel et public. Ce résultat est en accord avec la recommandation de Butts et al. (2019) et Noetel et al. (2020) qui suggèrent de mettre en avant le plaisir et les récompenses émotionnelles que le don génère pour encourager efficacement plus de dons.