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3 **InterMob: A 24-month randomised controlled trial comparing the effectiveness of an**  
4 **intervention including behavioural change techniques and free transport versus an**  
5 **intervention including air pollution awareness-raising on car use reduction among**  
6 **regular car users living in Grenoble, France**

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## A randomised controlled intervention to reduce car use

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## Abstract

**Background.** Frequent car use contributes to health and environmental issues such as air pollution, climate change and obesity. Active and sustainable mobility (bike, walk, public transport, car sharing) may address these issues. Different strategies have been implemented in past research, involving *hard* levers, aimed at modifying the economical or geographical context (e.g., free public transport), and *soft* levers, aimed at modifying psychological processes (e.g., personalised transport advice). However, few studies have combined both hard and soft levers. In addition, few have used robust methodologies (e.g., randomised controlled trials), followed behavioural changes in the long-term, and been anchored in behaviour change theories. InterMob aims to address these limits by implementing a 24-month randomised controlled trial including *hard* and *soft* levers. The objectives of InterMob are to a) evaluate the effectiveness of an experimental arm versus an active controlled arm, and b) identify the processes of mobility change.

**Methods.** Regular car users living in Grenoble ( $N = 300$ ) will be recruited and randomised to one of the two arms. The experimental arm consists in a six-month intervention combining *hard* levers (free access to transport/bikes), and *soft* levers (e.g., personalised transport advice). The control arm consists in a six-month intervention aimed at raising awareness on air pollution and its health effects. Both arms will include eight evaluation weeks (spread out over 24 months) based on a GPS, an accelerometer, and a pollution sensor. Moreover, participants will complete mobility logbooks and surveys measuring psychological constructs, socio-economical, and socio-spatial characteristics.

**Discussion.** InterMob will assess the effectiveness of two interventions aimed at reducing car use within regular car users in the short-, mid- and long-term. Moreover, InterMob will allow to better understand the psychological processes of behaviour change, and the socio-economical and geographical conditions under which the intervention is

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65 efficient in reducing car use. Finally, the benefits of mobility change in terms of physical  
66 activity, quality of life, and exposure to pollution will be quantified.

67 **Trial registration.** ClinicalTrials.gov: NCT05096000

68 **Keywords:** daily mobility, spatial organisation, psychology, car use, active mobility,  
69 sustainable mobility, behaviour change, health, air pollution, RCT

70

71 **InterMob: A 24-month randomised controlled trial comparing the effectiveness**  
72 **of an intervention including behavioural change techniques and free transport versus an**  
73 **intervention including air pollution awareness-raising on car use reduction among**  
74 **regular car users living in Grenoble, France**

75 **Background**

76 Daily car use contributes to major health and environmental issues. Motorised  
77 transport represents an important source of air pollution, noise and greenhouse gases  
78 (CITEPA, 2020; van Schalkwyk & Mindell, 2018; WHO, 2018). Moreover, regular car users  
79 present lower levels of physical activity (Chakrabarti & Shin, 2017), spend more time in  
80 sedentary behaviours (Sugiyama et al., 2012), and have a higher risk of being obese or  
81 overweight (Frank et al., 2004; Jacobson et al., 2011). In turn, air pollution, climate change  
82 and physical inactivity represent important dangers to human health and life expectancy  
83 (Fuller et al., 2022; Guthold et al., 2018; Kohl et al., 2012; Manisalidis et al., 2020).  
84 Nevertheless, despite all the negative consequences of daily car use, the car remains the main  
85 mode of transport in most countries (e.g., in France, 63% of daily trips are made by car,  
86 SDES, 2020).

87 Active and sustainable mobility such as cycling, walking, public transport and  
88 carpooling have in contrast positive effects on health and well-being. These modes of  
89 transport are associated with higher levels of physical activity (Chaix et al., 2014, 2019;  
90 Pucher et al., 2010; Rojas-Rueda et al., 2011), greater well-being (Martin et al., 2014), better  
91 work performances (Ma & Ye, 2019), and a higher life expectancy (Cepeda et al., 2017). In  
92 addition, these transport modes might represent an effective lever to tackle air pollution and  
93 climate change (Bernard et al., 2021; Brand et al., 2021). Nevertheless, active and sustainable  
94 mobility are less frequently used than the car for daily mobility (i.e., in France, 37% of daily  
95 trips are made by using an active and sustainable mobility, SDES, 2020).

## 96 **1.1 Strategies for car use reduction, active and sustainable mobility promotion**

97 During the last years, many interventions have been developed to reduce car use and  
98 promote active and sustainable mobility. They can be distinguished based on whether they  
99 involve *hard* or *soft* levers (Bamberg et al., 2011).

100 *Hard* levers are strategies that target a change in the geographical and economic  
101 context of individuals to encourage them to reduce car use and/or increase active mobility.  
102 Hard-lever interventions include for example the implementation of low-emission zones (i.e.,  
103 restricting the entry of polluting motorised transport into an established area), free public  
104 transport, city tolls or new cycling and walking infrastructures (Gärling & Schuitema, 2007;  
105 Kuss & Nicholas, 2022; Martin et al., 2012; Mölenberg et al., 2019). Results indicate that in  
106 general, *hard* levers seem to increase the use of active and sustainable mobility and reduce car  
107 use (e.g., implementing a payment for entering to the city centre reduces between 12 and 33%  
108 of city-centre cars in European cities, Kuss & Nicholas, 2022; infrastructural interventions in  
109 high-income countries increased in median relative, 22% of cycling behaviour compared to  
110 the baseline, Mölenberg et al., 2019).

111 *Soft* levers are strategies that target a change in psychological factors associated with  
112 mobility, such as individual's intention to use active modes of transport, self-efficacy and  
113 attitudes towards active mobility, mobility habits, etc. In the behaviour change literature,  
114 these levers refer to behaviour change techniques (Michie, Ashford, et al., 2011). In the field  
115 of mobility, some examples of behaviour change interventions are those proposing  
116 personalised transport advice, prompting mobility change goal setting and action planning,  
117 furnishing maps, transport schedules and other written materials (for reviews, see Arnott et  
118 al., 2014; Möser & Bamberg, 2008; Semenescu et al., 2020). The results concerning *soft*  
119 levers are more heterogeneous. While a meta-analysis and some systematic reviews show a

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120 lack of rigorous studies to allow a conclusion about the effects of these interventions (e.g.,  
121 Arnott et al., 2014; Graham-Rowe et al., 2011; Semenescu et al., 2020).

122 While past interventions have shown promising results, most of them share the same  
123 limitations. First, few studies rely on “robust” methodologies such as randomised controlled  
124 trials comparing the effects of an experimental intervention *vs.* a control intervention (e.g.,  
125 Graham-Rowe et al., 2011 identified only 14 studies among 77 studies considered as being  
126 “robust”). Second, few studies were anchored in behaviour change theories, and few describe  
127 the behaviour change techniques that were used to elaborate the intervention (e.g., Aittasalo et  
128 al., 2012; Fujii & Taniguchi, 2005; Mutrie et al., 2002). Third, most of the studies use only  
129 self-reported measures and no *in situ* sensors to measure behaviour (except from some  
130 exceptions like Aittasalo et al., 2019; Ben-Elia & Ettema, 2009). Fourth, few studies have  
131 mid- and long-term follow-ups (three months after the intervention or more, e.g., Aittasalo et  
132 al., 2012; Cellina et al., 2019; Hemmingsson et al., 2009; Mutrie et al., 2002; Thøgersen,  
133 2009). Fifth, most studies focused on only one type of lever, either *hard* or *soft* (e.g., In their  
134 meta-analysis, Semenescu et al., 2020 found only five interventions among 30 studies having  
135 combined soft and hard levers). InterMob study aims to address all of these limits.

### 136 **1.2 InterMob Study**

137 InterMob is a study that is part of the interdisciplinary Mobil’Air project that seeks to  
138 reduce air pollution in Grenoble, France (Mathy et al., 2020). More precisely, InterMob study  
139 combines concepts and methods from geography, psychology, economics, and epidemiology,  
140 with the aim to reduce car use and promote active and sustainable mobility in the Grenoble  
141 metropolitan area. InterMob seeks to address the aforementioned limitations by being  
142 anchored in behaviour change theories (see Figure 1). It also relies on a rigorous methodology  
143 (a randomised controlled study comparing an experimental and a control group). In addition,  
144 it proposes a longitudinal follow-up (eight weeks of measurement spread over 24 months), the

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145 experimental intervention contains *hard* and *soft* levers (e.g., free transport and behaviour  
146 change techniques), and it combines *in situ* objective measures and self-reported  
147 measurements, in order to collect data on mobility behaviours (e.g., through GPS sensors) as  
148 well as on their correlates (e.g., through questionnaires assessing intentions, habits,  
149 sociodemographic characteristics, etc.). Moreover, the content of the experimental group is  
150 elaborated by mobilising evidence- and theory-based approaches. Indeed, interventions that  
151 rely on a theoretical approach appear to be associated with larger effect sizes (Webb et al.,  
152 2010) and more consistent effects (McEwan et al., 2019). The active control arm includes  
153 sensibilisation to air pollution risks (*soft* lever). It targets attitudes, which have been identified  
154 as a factor of behavioral intention (e.g., theory of planned behavior). Such behavior change  
155 technique is expected to be less efficient in changing mobility behaviors than the techniques  
156 included in the experimental arm, the latter targeting more directly the intention-behavior gap.

157 In conclusion, InterMob is a 24-months randomised controlled trial, parallel group,  
158 two-arm, superiority trial with 1:1 allocation ratio.

159 The objectives of the study are to:

160 a) Evaluate the effectiveness of the InterMob intervention in reducing car use in the  
161 short- and in the long-term (one, three, seven, twelve, and twenty-four months after the  
162 beginning of the intervention).

163 b) Identify the mechanisms underlying mobility behaviours and behaviour change  
164 (e.g., psychological constructs such as intentions, self-efficacy, habits).

165 c) Identify the moderators of mobility change (i.e., the conditions and contexts under  
166 which the intervention is effective such as family context, degree of cyclability, trip chaining,  
167 work situation, activities organisation in space and time).

168



169           **1.3 Procedure for elaborating, implementing, and evaluating a theory- and**  
170 **evidence-base behavioural intervention**

171           To ensure the theory- and evidence-based character of the study, we followed a  
172 framework summarising the methodologies and recommendations already used in health  
173 psychology (Bartholomew et al., 2016; Desrichard et al., 2016; Hankonen & Hardeman, 2020;  
174 Michie, van Stralen, et al., 2011) (see Figure 1).

175           First, we reviewed the literature on the associations between air pollution, physical  
176 inactivity, and mobility behaviours. Then, we undertook a literature review in psychology and  
177 geography (e.g., De Witte et al., 2013; Ewing & Cervero, 2010; Lanzini & Khan, 2017; Van  
178 Acker et al., 2010) on the factors underlying daily mobility behaviour. Third, we carried out  
179 an interdisciplinary literature review to identify the strategies that have been successful in  
180 reducing car use and increasing active and sustainable mobility (e.g., Arnott et al., 2014; Bird  
181 et al., 2013; Martin et al., 2012; Semenescu et al., 2020). Fourth, we conceived a first version  
182 of the InterMob intervention, and conducted a pilot study to test its feasibility. Finally, we  
183 established the definitive version of InterMob that is detailed in this article. The present article  
184 follows the SPIRIT 2013 Guidance for protocols of critical trials (Chan, Tetzlaff, Altman, et  
185 al., 2013; Chan, Tetzlaff, Gotzsche, et al., 2013).

186           **2. Methods**

187           **2.1 Ethics and data protection**

188           The Figure 2 shows the details of the ethics and data protection process. First,  
189 InterMob study received the ethic's approval from Grenoble Alpes Research Ethics  
190 Committee (CERGA) in January 2019 (File CER Grenoble Alpes-Avis-2019-01-29-2).  
191 Moreover, as part of the application to the Ethics Committee, we carried out a Privacy Impact  
192 Assessment (PIA) to assess and avoid any potentially negative impacts of InterMob study on  
193 participants' data privacy. This procedure involved setting a discussion group with the data

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194 protection officer of the University, the people in charge of the data infrastructure at the  
195 university, and relevant representatives of the target population (members of a car-sharing  
196 platform, a local energy and climate agency, and a member of a pedagogical program about  
197 air pollution). During the discussion group, we talked about the potential implications of the  
198 data-collection tools (e.g., GPS sensors, detailed surveys that include data on psychological  
199 constructs as well as the geographic and socio-demographic context), and we detailed the  
200 proposed procedures and elements to ensure the respect of the General Data Protection  
201 Regulation (GDPR).

## 202 **2.2 Participants**

### 203 **2.2.1 Study Setting**

204 To detect the effects of InterMob study on car use reduction, recruitment will be  
205 restricted to individuals living and working in the Grenoble metropolitan area (see Figure 3),  
206 an urban area of south-eastern France (in the Alps) with a population size of approximately  
207 600,000 people. The topography of this area is characterised by being flat in the valleys  
208 (especially the Grenoble city) and surrounded by mountains (suburban areas). Car is the main  
209 transport mode for daily trips (53% of daily trips in the Grenoble metropolitan area are made  
210 by car, SMMAG, 2021).

### 211 **2.2.2 Eligibility criteria**

212 To take part in the InterMob study, participants will need to meet the following  
213 criteria:

- 214 • Being 18 years and older at the time of the eligibility interview;
- 215 • Living, working, studying, in the Grenoble metropolitan area;
- 216 • Having a car or motorbike as the main transport mode during the week (excluding the  
217 weekends);
- 218 • Travelling at least three days a week (excluding the weekends) by car or motorbike;

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- 219 • Motivated to reducing car use for daily trips, or having already started this reduction (i.e.,  
220 being in the contemplation, preparation or action stages of change according to Prochaska  
221 et al., 1994, 2008);
- 222 • Expecting to stay in the Grenoble metropolitan area for the duration of the study (24  
223 months).

224 All the eligibility criteria have been established by considering theoretical and  
225 practical aspects. For instance, theories in psychology suggest that participants who intend to  
226 change their behaviours do not need the same behavioural techniques than those not having  
227 such intention (e.g., Bamberg, 2013; Yang et al., 2010). More precisely, one of the main goals  
228 of behaviour change approaches is to help people to overcome the intention-behaviour gap  
229 (Sheeran & Webb, 2016).

### 230 **2.3 Participant timeline**

#### 231 **2.3.1 Recruitment, allocation, and blinding**

232 The participants will be recruited through different sources: mailing lists from former  
233 studies conducted by the research team (QAMECS-SHS and EMC<sup>2</sup> 2019-2020, local travel  
234 surveys, surveys from other laboratories and projects), publicity in local events related to  
235 transport or environment, publicity in community newspapers, intervention with the mobility  
236 referents of companies in the Grenoble region and, social networks (e.g., Facebook, LinkedIn  
237 and Instagram). The people that will be interested to participate in the InterMob study will fill  
238 up an online form in order to be contacted by a member of the implementation team (the  
239 information in this form includes the first name, a telephone number, an email address,  
240 municipality of residence, sex, age, educational attainment and the availability for receiving a  
241 phone call). The implementation team will call interested people to explain the study  
242 procedure and to administer the eligibility questionnaire. A few days later, the implementation  
243 team will call again the eligible people to ask if they accept to participate in the study. If a

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244 participant accepts, she/he will be randomly allocated to the experimental or active control  
245 arm. For this allocation, a randomisation list for the whole study was created by blocks of six  
246 before the beginning of the enrolment (i.e., it exists three possibilities to be in the  
247 experimental arm and three possibilities to be in the active control arm) by a member of the  
248 scientific team. The list was implemented in the management tool software developed by the  
249 team with WebDev for the study. The management tool automatically assigns each eligible  
250 participant to a group (the n-th participant is assigned to the group corresponding to the n-th  
251 position of the list).

252         Concerning blinding, the implementation team (programme implementers) will not be  
253 aware of group allocation at baseline (S0), but blinding will be impossible afterward, as the  
254 programme implementers deliver different contents to each arm through face-to-face  
255 interviews with participants. The researchers will not be aware of group allocation at any  
256 time, and the researchers responsible for analysing the data will be blinded to the treatment  
257 allocation. Double blinding will not be possible given that allocation concealment is  
258 impossible for participants in such an intervention.

### 259                 **2.3.2 Timeline of the Study**

260         Participants enrolled in the study will have a first two hours with a programme  
261 implementer (“Session 0” or S0, see Figure 4). At the beginning of this meeting, the participant  
262 reads and signs an informed consent form (cf. Supplementary materials). She/he fills up a first  
263 questionnaire assessing her/his quality of life, biometrics, mobility behaviours, the weekly  
264 duration of moderate-to-vigorous physical activity, socio-demographic information and  
265 psychological constructs 1, 2 and 3, as well as a mobility logbook assessing her/his last week  
266 mobility (for more details about the tools and surveys, see Table 1). Then, the implementation  
267 team explains how to correctly carry the Sensedoc<sup>TM</sup> and MicroPem<sup>TM</sup> sensors (see Figure 5),  
268 and the participant is instructed to start carrying them from the next seven days. At the end of

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269 the session, the sensors are collected by the programme implementer. Moreover, during this  
270 session, the participants receive a daily survey on their telephones measuring psychological  
271 constructs 4. Two weeks after S0, the participants have the first intervention appointment (S0+)  
272 that will be described in the intervention subsection.

273         Approximately one month after the beginning of the study, participants have the second  
274 meeting of the intervention (1 hour) and start a new session of measurement (S1). During this  
275 session, they carry a Sensedoc<sup>TM</sup> and answer the same surveys as in S0. Approximately 3.5  
276 months after the start of the study, the participants have the third session (S2) containing the  
277 same elements as in S0 except for the pollution sensor. Then, about seven months after the start  
278 of the study, the intervention is finished and immediately after the end of the intervention, the  
279 participants have the fourth session (S3) during which they carry the Sensedoc<sup>TM</sup> and the  
280 MicroPem<sup>TM</sup> and answer the same surveys as in S0. Around nine months after the start of the  
281 study, participants start the fifth session (S4), they do not carry any sensors but fill up a mobility  
282 logbook and answer the same as in S0. Twelve months after the start of the study, participants  
283 start the sixth session (S5) with the same protocol as S4. Eighteen months after starting the  
284 study, participants start the seventh session (S6) following the same protocol as S0. Finally, 24  
285 months after starting the study, participants start the eighth session (S7) and follow the same  
286 protocol as S4 and S5 (see Figure 4).

287         All the sessions are scheduled with our management tool by considering the availability  
288 of the programme implementers. This internal tool is central to implement and chart all steps  
289 of the intervention.

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### 292 **2.3.3 Retention of participants**

293 To limit the attrition risk, the implementation team will send a newsletter including  
294 information about the study (e.g., recruitment ratios) and the research team (interviews,  
295 recommended scientific articles) a few times a year. Moreover, participants taking part in  
296 the study until the session 2 will be drawn to win a connected watch.

### 297 **2.3.4 Power Analysis and Sample Size**

298 Sample size is difficult to estimate when using multilevel modelling as in the present  
299 study, given that sample size calculation is sensitive to the values of all the fixed and random  
300 parameters included in the models. As such, we estimated the sample size based on the  
301 expected effect size of the intervention at the end of the intervention only, which was an  
302 expected difference of 17% of the trips made by car at the end of the intervention (Brockman  
303 & Fox, 2011) between the experimental and the control group. With a significance level of  
304 0.05 and a statistical power of 80%, the *a priori* power analysis conducted with G\*Power  
305 3.1.9.4 (Erdfelder et al., 2009; Faul et al., 2007) indicated that 150 participants per arm (a  
306 total of 300 participants) are necessary for finding a difference of 17% between the  
307 experimental and the control arms at the end of the intervention. We will therefore recruit  
308 participants until exhaustion of our financial and human resources, with this ideal target of  
309 150 participants per arm. Once recruitment is finished, we will compute the minimal  
310 statistically detectable effect that can be observed based on the final number of participants  
311 (Lakens, 2022).

## 312 **2.4 Interventions**

313 Eligible participants will be randomised in equal proportion to the experimental arm or  
314 to the active control group. The duration of both interventions will be the six first months of  
315 the 24-month study period (Figure 4). The detailed content of each arm will be described in  
316 the next subsections.

**317 2.4.1 Experimental Arm**

318 The participants attributed to the experimental arm will receive a free six-month  
319 transport pass and/or a six-month free access to a classic or electric bike (behavioural  
320 technique classified as “12.5 Adding objects” according to Michie, Ashford, et al., 2011).  
321 They will have two meetings with a programme implementer who will deliver behavioural  
322 change techniques, including a discussion about the motivation to change (behavioural  
323 techniques known as “motivational interviewing” and “5.2 salience of consequences”  
324 according to Hardcastle et al., 2012; Michie, Ashford, et al., 2011), personalised transport  
325 advice (behavioural technique classified as “4.1 Instructions on how to perform the  
326 behaviour” according to Michie, Ashford, et al., 2011), a mobility change goal setting and  
327 action planning (behavioural techniques classified as “1.1 Goal setting” and “1.4 Action  
328 planning” according to Michie, Ashford, et al., 2011), and obstacles’ prevention (behavioural  
329 technique classified as “1.2 Problem solving” according to Michie, Ashford, et al., 2011).

330 More precisely, during the first intervention appointment with the programme  
331 implementer called “S0+” (1.5 hours), the participant and the programme implementer will  
332 discuss about the motivations to change, they will work together on a personalised transport  
333 advice considering the participant’s needs, constraints and preferences, the participant will set  
334 some change goals and elaborate an action plan, and he/she will examine the possible  
335 obstacles to change and how to prevent them. During the second meeting (1 hour, see  
336 Figure 4), the programme implementer and the participant will assess and adapt the  
337 previously established goals, they will work on an updated personalised transport advice (if  
338 the participants ask for it), and on resolving any obstacles they met since the first meeting that  
339 have not been resolved.

340 Following the first meeting of the intervention, participants will be prompt to fill up a  
341 “goal notebook” during the six months of the intervention, by setting or reviewing their goals

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342 every two weeks, and by taking notes of the experienced obstacles. In addition, they will  
343 receive weekly SMS during the first three months of the intervention, and bimonthly SMS  
344 during the last three months of the intervention, to a) prompt goal setting and try to keep the  
345 same contexts for the goals like the same trips or the same transport modes (behavioural  
346 techniques classified as “1.7 Review outcome” and “8.2 Habit formation” according to  
347 Michie, Ashford, et al., 2011) and b) prompt self-monitoring related to the consequences of  
348 mobility change (e.g., a more important well-being; behavioural technique classified as “2.4  
349 Self-monitoring of outcomes” according to Michie, Ashford, et al., 2011).

#### 350 **2.4.2 Active Control Arm**

351 The participants in the active control arm will also have two meetings with a programme  
352 implementer, of the same duration as in the experimental arm. During the first 1.5 hour meeting  
353 “S0+”, the programme implementer and the participant will discuss about air pollution (i.e.,  
354 definition of air pollution sources, population most impacted, air pollution levels in Grenoble,  
355 health consequences of pollution and pollution peaks), about the association between air  
356 pollution and mobility (i.e., participants and programme implementer discuss about the  
357 exposure of car drivers and bike drivers to air pollution), and about the advantages of  
358 commuting by car (behavioural technique classified as “5.2 Salience of consequences”  
359 according to Michie, Ashford, et al., 2011). During the second 1-hour meeting, the participant  
360 and the programme implementer will discuss of the air quality of the last weeks and check if  
361 there were some pollution peaks during the last weeks (behavioural technique classified as 5.2  
362 Salience of consequences, according to Michie, Ashford, et al., 2011).

363 Following the first meeting, participants will be prompt to fill up an “observation  
364 notebook” during the six months of intervention, by taking notes of air quality and of every  
365 announcement of pollution peak every two weeks. In addition, they will receive weekly SMS  
366 during the first three months of the intervention, and bimonthly SMS during the last three



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367 months of the intervention, to prompt taking notes of a) air quality and b) any pollution peak  
368 announced in the television/radio/telephone (see Table 2 for a summary of the interventions for  
369 the experimental and active control arms).

### 370 **2.4.3 Adherence**

371 To measure the adherence to each intervention arm, the programme implementer will  
372 take notes of the duration of each meeting and of every situation that could disrupt the  
373 planned content of the intervention (e.g., participants that do not receive any personalised  
374 transport advice). Moreover, one item in the deployed surveys will assess whether the  
375 participant sets goals (i.e., Intention implementation towards active mobility survey, see  
376 Table 1).

## 377 **2.5 Outcomes and data collection**

### 378 **2.5.1 Primary outcome and data collection methods**

379 The main outcome of InterMob study will be the reduction of car use measured by  
380 kilometres travelled by car and the modal share of the car. This outcome will be calculated from  
381 segmented and enhanced GPS tracks obtained from a sensor containing a triaxial accelerometer  
382 and a continuous GPS tracking MAX-M8 Global Navigation Satellite System receiver from u-  
383 blox (Sensedoc™ 2.0, see Figure 5), and by a mobility logbook (i.e., a paper notebook  
384 collecting detailed information on the activities and trips made each day, such as departure and  
385 arrival times, the address of the arrival point; the transportation mode, the number of people  
386 making the trip with the participant). More precisely, The SenseDoc™ 2.0 acquires GPS data  
387 each second et accelerometry with a frequency of 60hz.

### 388 **2.5.2 Secondary outcomes and data collection methods**

389 Secondary outcomes will include the following variables associated with mobility  
390 behaviours: kilometres travelled by active and sustainable mobility, and the modal share of  
391 active mobility, physical activity measured by the Sensedoc™ 2.0 sensor and the IPAQ (i.e.,

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392 International Physical Activity Questionnaire, Craig et al., 2003), exposure to air pollution (i.e.,  
393 concentration of fine particles PM<sub>2.5</sub> and oxidative potential) measured by an air pollution  
394 sensor (MicroPem™), activity programme measured by the mobility logbook and, quality of  
395 life measured by a survey (Ware et al., 1996) (see Figure 5).

### 396 **2.5.3 Mediators, moderators, and collection methods**

397 We will investigate whether the effects of the intervention on mobility-related outcomes  
398 are mediated by several psychological constructs, including notably attitudes and self-efficacy  
399 towards the car (Godin, 2012), active mobility habits (Gardner et al., 2012), motivational stages  
400 of mobility change (Biehl et al., 2018) (see Table 1 for all the details), which will be collected  
401 by online surveys, using the platform Sphinx iQ2 v 7.3.1.0 (this platform is located at the  
402 university to ensure that the data remain in Europe as required by the European data protection  
403 law). Self-control constructs, including subjective vitality (Ryan & Frederick, 1997),  
404 temptation, conflict, and resistance (Hofmann et al., 2012), will be measured on a daily basis  
405 during the data collection weeks, through online surveys on the platform Sphinx iQ2 v 7.3.1.0  
406 as well.

407 We will also investigate if the efficacy of the intervention depends on several socio-  
408 demographic and geographic variables, including the number of children, number of cars, trip  
409 chaining, mobility biographies (Müggenburg et al., 2015), cyclability and density of home  
410 address and destination address. They will be measured through the data collected by the online  
411 surveys, on the platform Sphinx iQ2 v 7.3.1.0.

### 412 **2.5.4 Reach and Quality of the Implementation**

413 The reach of the intervention (i.e., the number of people contacted by the implementation  
414 team, the number of eligible participants, and the enrolled participants) will be assessed by  
415 collecting the data from the first contact to the enrolment of participants. Finally, the quality  
416 of the implementation will be assessed by analysing a document filled up by the programme

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417 implementer at every appointment related to the intervention (i.e., a checklist for every task to  
418 be done during the S0+ and S1 appointments).

## 419 **2.6 Data management and statistical methods**

### 420 **2.6.1 Data quality, management, storage, access and confidentiality**

421 In order to monitor the quality of the data, one member of the implementation team  
422 and few members of the scientific team checks the correct completion of logbooks, online  
423 questionnaires, and the presence of missing data collected by the sensors.

424 Data from the sensors (Sensedoc<sup>TM</sup> and MicroPem<sup>TM</sup>) are downloaded after each  
425 session to an encrypted computer and stored on a secure and back-up online storage. Data  
426 from the online surveys are downloaded twice a month on the same computer. Furthermore,  
427 data from all devices (contact forms, sensors, mobility logbooks and online surveys) will be  
428 structured and saved in two different blocks stored on distinct servers:

429 Block 1 will contain the contact file with the names, addresses and contact details of  
430 participants for setting the appointments and sending/recovering material. This file will be in  
431 the management tool, encrypted and kept separate from other data by the implementation  
432 team coordinator. The correspondence table between the code of the participants and their  
433 name will also remain in the management tool, a software as a service (SaaS) deployed on a  
434 specific server of the university infrastructure accessible only by the implementation team.

435 Block 2 will contain all the collected data from surveys and sensors. They will be  
436 stored locally, on the secured data centre of the university, with access restricted only to  
437 InterMob faculty members and implementation team, in line with data protection law. The  
438 raw data will be stored by the programme implementers. The data from the  
439 GPS/accelerometer and pollution sensors will be downloaded at each return from the field.  
440 The survey data, coming from the Sphinx platform, will be regularly uploaded to the storage  
441 space. Only implementation team and informatician administrators will have read/write

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442 access. The scientific team will only have read access to raw data. Moreover, they have  
443 folders with data pre-processing and processing with read/write access, not accessible to the  
444 implementation team. Finally, another folder will be created for sharing with external  
445 partners.

### 446 **2.6.2 Data monitoring, harms and auditing**

447 No data monitoring committee has been set up for this study because there is no strong  
448 suspicion that the interventions can potentially harm the participants. Nevertheless, there is a  
449 risk that some travel modes (e.g., cycling) might lead to traffic accidents. For this reason and  
450 in order to protect the participants as much as possible, the helmets will be mandatory  
451 throughout the study. At the psychological level, some participants may experience guilt if  
452 they do not manage to reduce car use. In order to limit this risk, the team responsible for the  
453 implementation insists on a non-guilty and valorising communication and coaching during  
454 their face-to-face meetings with the participants (i.e., motivational interviewing). Moreover,  
455 participants will be encouraged to share with the implementation team any adverse events  
456 associated to mobility change. This information will be stored in a specific document by the  
457 coordinator of the implementation of the study.

458 The coordinator of the implementation of the study and the coordinators of the project  
459 have one meeting per week to audit the trial conduct.

### 460 **2.6.3 Ancillary and post-trial care**

461 No ancillary and post-trial care will be provided.

### 462 **2.6.4 Statistical methods**

#### 463 **2.6.4.1 Analysing the effects of the intervention on primary and** 464 **secondary outcomes by using multilevel modelling**

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465 The analysis of the effectiveness of the intervention on the primary outcome  
466 (reduction of car use, see section 2.5.1) and secondary outcomes (mobility-related variables  
467 described in section 2.5.2) will be examined at the very short term (three months after the start  
468 of the intervention: S2), the short term (seven months after the start of the intervention: S3),  
469 the medium term (one year after the start of the intervention: S5) and the long term (18  
470 months after the start of the intervention: S6). More precisely, we will test the differences in  
471 car use reduction between the experimental arm and the active control arm, by using  
472 multilevel modelling, which is appropriate when data are nested, as it is the case here with  
473 several measurement times per participant (e.g., Boisgontier & Cheval, 2016). Moreover,  
474 multilevel modelling offers the possibility to analyse incomplete data sets, which is  
475 particularly relevant given the duration of the study, which makes likely the occurrence of  
476 missing data (Judd et al., 2012). For this purpose, we will follow the steps recommended by  
477 Field et al. (2012):

- 478 1) Prepare the data by differentiating between- and within-individual constructs.
- 479 2) Centre the within-individual variables by participant (i.e., “group centring”).
- 480 3) Create a first “constraint” model (a model containing all the random and fixed  
481 variables of the final model) and a “null” model including only the “intercept”  
482 equal to 1 and only one random variable associated with the identity of the  
483 participant (i.e.,  $1 | Id$ ) to check the intraclass correlation coefficients (ICC).
- 484 4) Build the main model.
- 485 5) Evaluate the normal distribution of residuals, Cooks distance and influential cases.

486 The main model will include the following fixed effects: arm, time, and arm x time  
487 interaction, with random intercepts for participants and random linear slopes for repeated  
488 measures at the participant level.

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489 Moreover, the statistical analysis will follow intention-to-treat principles. This means  
490 that once a participant has been randomly assigned to an arm (i.e., experimental or control),  
491 his/her data will be included in the analysis (McCoy, 2017). More precisely, even if a  
492 participant has not adhered to the intervention or has not finished the study, his/her data will  
493 be included to all the analysis.

494 In addition, we will carry attrition analysis by comparing the characteristics of the  
495 participants that drop out the study and the participants that completed the study (e.g.,  
496 compliance with eligibility criteria, sociodemographic and geographical characteristics).

#### 497 **2.6.4.2 Analysis of the mediators of the effects of the intervention**

498 To analyse the mechanisms explaining potential effects of the intervention on car use  
499 reduction and mobility-related variables, the investigators will use multilevel mediation  
500 models to test the mediating role of psychological constructs (e.g., intention toward active and  
501 sustainable mobility, active mobility habits, self-efficacy towards active mobility) in the  
502 intervention mobility-related variables relationships.

#### 503 **2.6.4.3 Analysis of the moderators of the effects of the intervention**

504 To analyse the possible moderators of the effects of the intervention on car use  
505 reduction and mobility-related variables, the investigators will assess in multilevel models the  
506 statistical interactions between socio-demographic, geographic and psychological variables  
507 (e.g., number of children, travelled distances, accessibility of home and work, self-control  
508 variables) and the allocation to the experimental or control arm. This will allow identifying to  
509 what extent geographical, socio-demographic, and psychological variables moderate the  
510 effects of the intervention on car use reduction and mobility-related variables.

### 511 **3. Discussion**

512 InterMob study is a 24-month randomised controlled trial aiming to reduce car use of  
513 car and motorbike regular drivers. For this purpose, InterMob will include a two-arm

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514 intervention of six months: an experimental arm that combines the use of behaviour change  
515 techniques previously identified as being successful at changing mobility behaviour (e.g.,  
516 personalised transport advice, goal setting, action planning) and free access to public transport  
517 or/and to a bike; and an active control arm which will target raising awareness about the  
518 consequences of air pollution and the link between air pollution and car use.

519 InterMob will aim to address the limitations of prior behaviour change interventions in  
520 the field, including lack of theory-based intervention elaboration, long-term follow-ups, high-  
521 quality methodologies (e.g., randomised controlled trial), and *in situ* measures (Arnott et al.,  
522 2014; Dixon & Johnston, 2021; Hoffmann et al., 2014; Petrunoff et al., 2016; Yang et al.,  
523 2010). By addressing these limitations, InterMob will allow deepening our knowledge of the  
524 long-term effects of a theory-based intervention tested in a 2-arm randomised controlled trial  
525 that combines *hard* and *soft* levers, with use of *in situ* measures of mobility and correlates.

526 Furthermore, we will aim to understand the psychological mechanisms that explain the  
527 potential effects of the proposed intervention on mobility, as well as the moderating role of  
528 geographical, socio-demographic, and psychological factors in this relationship, to better  
529 understand the conditions under which the intervention is effective.

530 Finally, InterMob study will measure the effects of the intervention not only on  
531 mobility change, but also on health-related outcomes such as physical activity and exposure to  
532 air pollution. Therefore, the results of our study might imply supplementary arguments for  
533 governments and politicians to promote car reduction and active and sustainable mobility, and  
534 deepen what has been modelled in past studies (Bouscasse et al., 2022).

#### 535 **4. List of Abbreviations**

536 GPS: Global Positioning System

#### 537 **5. Declarations**

##### 538 **5.1 Ethics approval and consent to participate**

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539 InterMob study was approved by Grenoble-Alpes Ethics Committee (File CER  
540 Grenoble Alpes-Avis-2019-01-29-2) in January 2019. Moreover, each participant reads and  
541 signs a detailed informed consent form (cf. Supplementary materials) if he/she agrees to  
542 participate in InterMob study before starting the study.

### 543 **5.2 Consent for publication**

544 All listed authors consented the publication of the manuscript.

### 545 **5.3 Availability of data and material**

546 The anonymized and aggregated dataset and the codes used to analyse data will be  
547 available after the end of the data analysis in the open science framework:

548 [https://osf.io/9anpg/?view\\_only=3cba7f109a984abbbc4408fcfa0f8618](https://osf.io/9anpg/?view_only=3cba7f109a984abbbc4408fcfa0f8618) with the DOI  
549 10.17605/OSF.IO/9ANPG.

### 550 **5.4 Competing interests**

551 Free public transport and free access to conventional or electric bicycles will be  
552 financed by Grenoble-Alpes Métropole, SMMAG (Mixed Syndicate of Mobilities of  
553 Grenoble area) and Région Auvergne-Rhône-Alpes that are key players in mobility, health,  
554 and environmental issues.

### 555 **5.5 Funding**

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557 framework of the “Investissement d’avenir” IDEX programme (ANR-15-IDEX-02) for the  
558 Mobil’Air research program. It also received support from the funding partners of the IResP  
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562 Grenoble-Alpes Metropole. The funding sources had no role in determining the design nor the  
563 execution, analysis, or interpretation of the data.



564 **5.6 Authors' contributions**

565 CT-E drafted the manuscript under the supervision of AC and SD. All the authors critically  
566 appraised the manuscript, worked on its content, and approved the final version for  
567 submission. AC and SC contributed equally to the conception and coordination of this article.

568 **5.6.1 Composition, roles, and responsibilities in the project**

569 AC and SC are the scientific coordinators of the project. LL is the coordinator of the  
570 implementation of the study. CT-E elaborated and formulated the details of the intervention  
571 under the supervision of AC, SD, and SC. All authors developed the study concept,  
572 contributed to improving the study design and data collection, and approved the final version  
573 of this study.

574 **5.7 Acknowledgements**

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576 Alpes Region, the SMAAG and, the Grenoble-Alpes Metropole.

577 **6. Trial registration**

578 ClinicalTrials.gov: NCT05096000 on 27/10/2021 (retrospectively registered).

579 <https://clinicaltrials.gov/ct2/show/NCT05096000>

580 **7. Protocol version and protocol amendments**

581  
582 This version of the protocol (2.0) is dated 1 June 2022. Any changes in the protocol

583 will be communicated and shared on ClinicalTrials.gov

584 <https://clinicaltrials.gov/ct2/show/NCT05096000>

585 **8. Dissemination policy**

586 The results of the study will be published in scientific journals and open science  
587 platforms. In addition, the results of the study will be written up in a user-friendly style to be  
588 sent to all participants and partners of the study after the end of the study.

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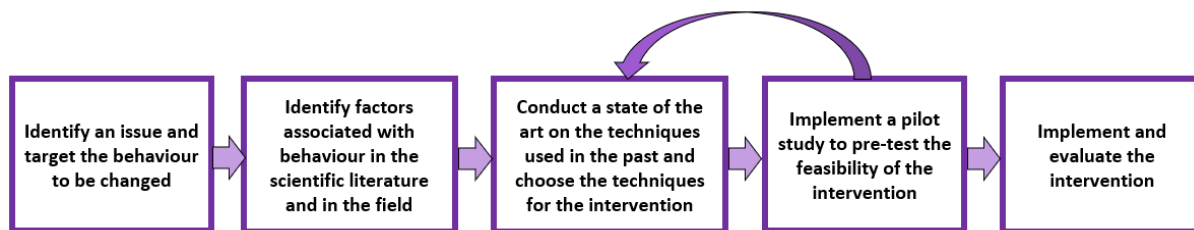
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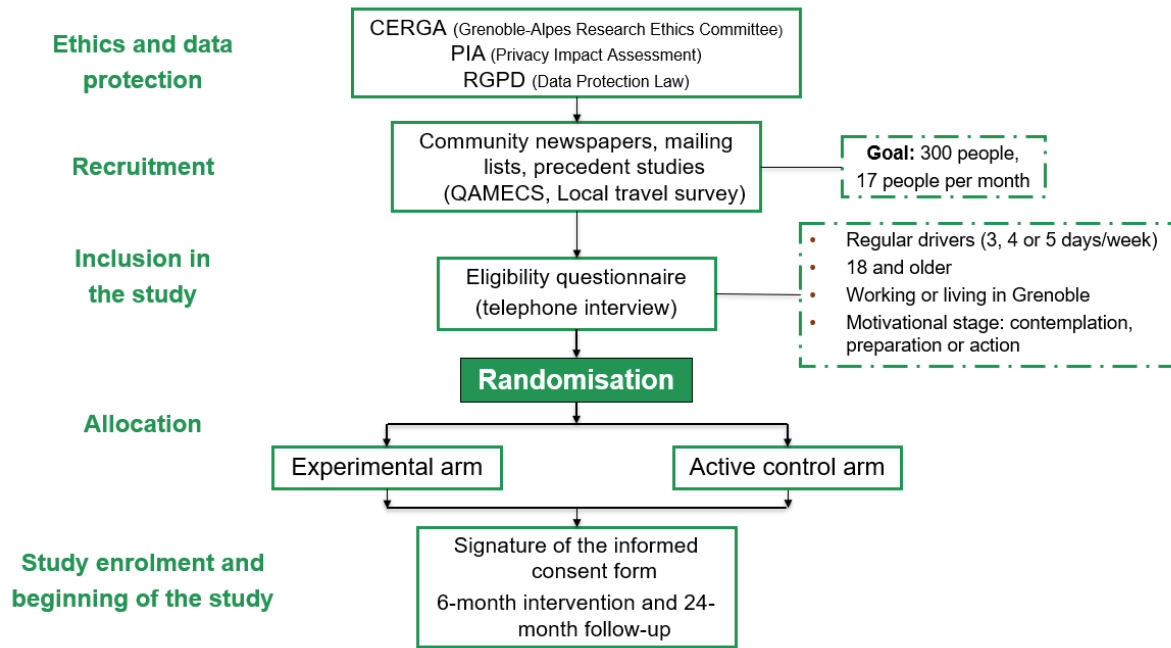
## Figures

887



888 *Figure 1.* Followed steps for the elaboration, implementation and evaluation of InterMob (the  
889 proposed methodology summarises the methodologies proposed by Bartholomew et al., 2016;  
890 Bartholomew, 2011; Desrichard et al., 2016; Michie, van Stralen, et al., 2011).

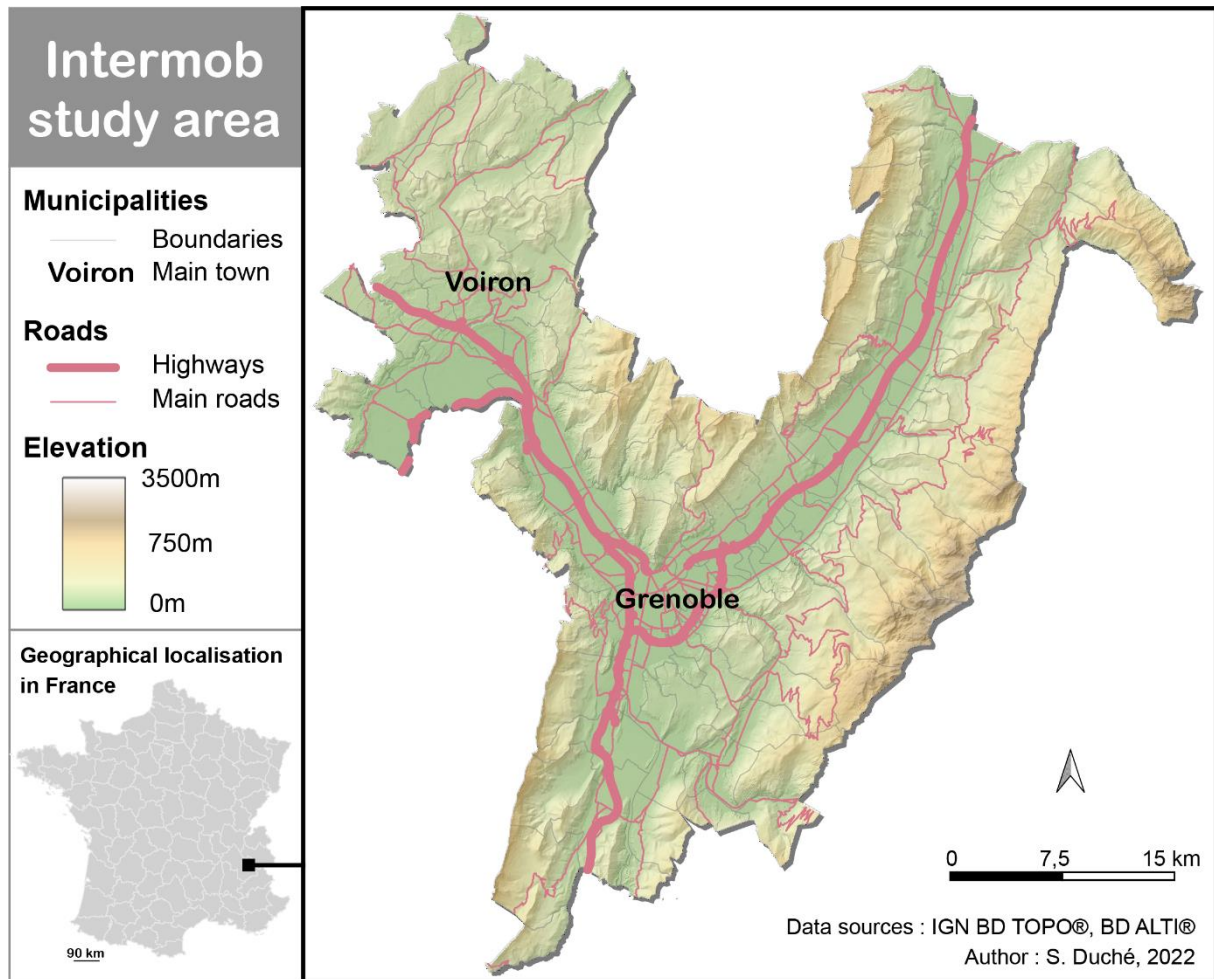
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892 *Figure 2.* Procedure of the InterMob study since the ethics and data protection procedures to

893 the study enrolment and beginning of the study.

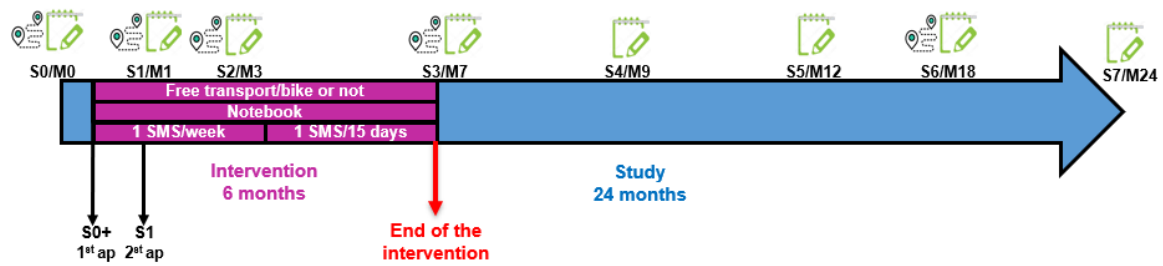


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895 *Figure 3. Map of Intemob study area.*



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896

897 *Figure 4.* Calendar of the intervention and the measurements. S = Session (seven-day  
 898 measurement), M = Month, ap= appointment being part of the intervention.  represents  
 899 seven days of carrying a Sensedoc and a MicroPem (the air pollution sensor is only carried  
 900 during the sessions 0, 3 and 6),  represents seven days of filling up a mobility logbook,  
 901 answering a long survey (one time) and a short daily survey.

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902

903 *Figure 5.* Data collection sensors. In the left side, Sensedoc™ sensor (Accelerometer and GPS)

904 which should be worn in a belt around the waist. In the middle, MicroPem™ (pollution sensor)

905 which should be worn in a bag or purse with the pipe as close to the airway as possible. In the

906 right side, the MicroPem™ and the Sensedoc™.

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907

## Tables

908 Table 1. Summary of the outcomes, tools and time measurements.

Outcome	Tool	Time measurement										
		R	S0	S0+	S1	S2	S3	S4	S5	S6	S7	
<b>Principal outcome</b>												
Car use reduction (kilometers and modal share)	Sensedoc and/or mobility logbook		✓ <sup>abc</sup>		✓ <sup>abc</sup>	✓ <sup>abc</sup>	✓ <sup>abc</sup>		✓ <sup>bc</sup>	✓ <sup>bc</sup>	✓ <sup>ab</sup>	✓ <sup>bc</sup>
<b>Secondary outcomes</b>												
Use of active and sustainable mobility (kilometers and modal share)	Sensedoc and/or mobility logbook		✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>
Minutes of moderate and vigorous physical activity	Sensedoc and/or IPAQ (Craig et al., 2003)		✓ <sup>a</sup>		✓ <sup>a</sup>	✓ <sup>a</sup>	✓ <sup>a</sup>	✓	✓	✓ <sup>a</sup>	✓	
Exposure to air pollution	MicroPem		✓				✓			✓		
Carbon footprint related to transport	Calculation based on the travelled kilometers and the mode of transport		✓ <sup>c</sup>		✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>
Quality of life	Survey SF-12 (Ware et al., 1996)		✓			✓	✓		✓	✓	✓	
Biometrics	Biometrics survey (size and weight)		✓ <sup>c</sup>		✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>			✓ <sup>c</sup>		
Activity programme	Mobility logbook		✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>	✓ <sup>c</sup>
Mobility diagnosis	Survey		✓									
Accessibility by public transport and bicycle	Calculation of spatial information through a survey		✓ <sup>c</sup>									
Cyclability	Calculation of spatial information through a survey		✓ <sup>c</sup>									
Socio-demographic information survey	Survey		✓									
Socio-demographic follow-up survey	Survey				✓	✓	✓	✓	✓	✓	✓	✓
Psychological constructs survey part 1			✓				✓	✓	✓	✓	✓	✓
Stage of mobility change	Adapted survey (Biehl et al., 2018)		✓				✓	✓	✓	✓	✓	✓

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Associated mobility habits	Adaptated survey (Buhler, 2012)	✓	✓	✓	✓	✓	✓	✓	✓
Green identity	Survey (Lalot et al., 2019)	✓	✓	✓	✓	✓	✓	✓	✓
Psychological constructs survey part 2		✓	✓	✓	✓	✓	✓	✓	✓
Mobility habits	Adapted survey (Gardner et al., 2012)	✓	✓	✓	✓	✓	✓	✓	✓
Intention towards mobility	Adapted survey (Godin, 2012)	✓	✓	✓	✓	✓	✓	✓	✓
Mobility self-efficacy	Adapted survey (Godin, 2012)	✓	✓	✓	✓	✓	✓	✓	✓
Intention implementation towards active mobility	Adapted survey (Godin, 2012)	✓	✓	✓	✓	✓	✓	✓	✓
Mobility attitudes	Adapted survey	✓	✓	✓	✓	✓	✓	✓	✓
Perceived risks of COVID-19	(Nexøe et al., 1999)	✓	✓	✓	✓	✓	✓	✓	✓
Mobility subjectives norms	Adapted survey (Godin, 2012)	✓	✓	✓	✓	✓	✓	✓	✓
	Adapted survey	✓	✓	✓	✓	✓	✓	✓	✓
Psychological constructs survey part 3		✓							
Satisfaction with travel	Adapted survey (Ettema et al., 2011)								
Mobility motivation	Adapted survey (Boiché et al., 2019)								
Psychological constructs survey part 4		✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>
Subjective vitality	Adapted survey (Ryan & Frederick, 1997)	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>
Tentation and conflict	Adapted survey (Hofmann et al., 2012)	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>	✓ <sup>b</sup>
Reach of the intervention	Ratio of contacted people, eligible and enrolled people	✓ <sup>c</sup>							
Quality of the implementation	Checklist for every intervention meeting (answered by the programme implementer)		✓ <sup>c</sup>	✓ <sup>c</sup>					

909 **Note.** By default, the outcomes were measured by using a survey that was filled in at the beginning of the session. S= Seven-day measurement  
910 session (except from S0+ that indicated the first intervention meeting), R= Recruitment and enrolment periods. <sup>a</sup> indicates that the outcome was  
911 measured with a sensor, <sup>b</sup> indicates that the outcome was measured on a daily basis, <sup>c</sup> indicates that the outcome was calculated by a member of  
912 the research team based on other data.

Table 2. Summary of the elements of the experimental and the active control arms.

<b>Element</b>	<b>Experimental arm</b>	<b>Active control arm</b>
<b>Material incentive</b>	6 months of free transport and/or 6 months of free access to a classic or an electric bike	
<b>2 appointments with a programme implementer</b>	First appointment: Discussion about the motivations to reduce car use, co-construction of a personalised mobility advice, mobility change goals setting, development of an action plan, prevention of obstacles to change mobility behaviour. Second appointment: Evaluation and adaptation of change goals and resolution of obstacles	First appointment: Concept of air pollution, in-depth questions on pollution (sources of air pollution, health consequences, pollution levels in Grenoble metropolitan area), discussion about the association between air pollution and car use and discussion about the benefits and advantages of the frequent use of the car Second appointment: Evaluation and discussion of the air quality and the identified pollution peaks
<b>Notebook to be filled up</b>	Goals notebook: 1. Setting new goals or adapting goals every two weeks 2. Taking notes of the experienced obstacles and looking for solutions	Observation notebook: 1. Taking note of the air pollution every two weeks 2. Taking note of the announced air pollution peaks (if any)
<b>2 kinds of SMS (1 SMS per week during the first 3 months and 1 SMS bimonthly during the last six months)</b>	1. Prompting the Setting and the Adaptation of goals, action planning and, habit formation 2. Self-monitoring of positive consequences of mobility change (e.g., better physical state, feeling of well-being)	1. Taking notes of the air pollution indices and comments 2. Taking notes of the announced air pollution peaks and comments