# Risk of late cervical cancer screening according to prosperity and medical density in daily frequented neighborhoods in Greater Paris.

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**Research**

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# Abstract

Background: The consideration of multiple spaces frequented daily by individuals is attracting interest for the analysis of socioterritorial health and healthcare inequalities in light of the high daily mobility in urban settings and the increasing availability of mobility data. Our objective was to estimate the associations between attributes of daily frequented neighborhoods and delayed cervical smear tests in the Greater Paris area.

Methods: Data were extracted from the 2010 SIRS cohort survey. Participants could report three neighborhoods (residence, work, and the next most regularly frequented). All multivariate analyses were conducted: simple multilevel logistic regression models, cross-classified multilevel logistic regression models were used to simultaneously consider the three types of neighborhoods studied (residential, work or study, visit) with active and mobile women. Finally, associations with socioeconomic and medical diversity scores (adjusted for the five individual characteristics) were estimated by logistic regression models that took sampling design into consideration.

Results: One-quarter of the women reported that they had not had a smear test in the previous three years. After adjusting for individual characteristics, there was a significant association between the socioeconomic and medical diversity scores for the multiple neighborhoods frequented and the risk of a delayed smear test. Women who reside and work in poor neighborhoods and whose next most regularly frequented neighborhood was also poor had a significantly higher risk of late cervical cancer screening.

Conclusions: In the characterization of social and territorial inequalities in healthcare, social epidemiology and health geography show a growing interest in considering multiple spaces frequented daily by individuals. A cumulative exposure score, such as the one presented here, may be a relevant approach for analyzing their effects.



Keywords: Multilevel analysis, neighborhood, daily mobility, cancer prevention, cervical cancer, social inequalities, Paris area


# Background

Social-territorial inequalities are the systematic differences observed in the health status of different social groups and between different contexts of population.

In recent years, numerous studies have shown how spatial influence, often considered exclusively in terms of the standards of one's residential area, affects different health indicators and resources [1–2]. Some have emphasized the limitations of examining only the individuals' residential living areas (their neighborhood of residence) and disregarding their daily mobility and exposure to multiple spaces. Recently, studies have shown an interest in considering spaces other than the residential one only [3] to prevent the "local trap" risk [4]. In addition, residents' daily mobility has been increasingly considered during urban planning for the purpose of identifying needs for public transportation and other public

equipment and services, but less so for healthcare services, at least in France. The consideration of multiple spaces frequented daily by individuals is attracting interest for the analysis of socioterritorial health and healthcare inequalities in light of the high daily mobility in urban settings and the increasing availability of mobility data [5–8].

Greater Paris is a region where strong sociospatial segregation can be seen throughout the day [9]. The strongest segregation indices are observed for the highest social categories, such as business leaders, the liberal professions, information, the arts and entertainment professions, high-ranking officials and senior bureaucrats [10]. However, the poorest neighborhoods continue to falter because of high unemployment rates, which have increased since the 2006 economic crisis, especially for women [11]. This social segregation is superimposed with drastic spatial disparities in the supply of healthcare. The central area of Paris and its bordering suburbs are densely populated and well-off and are therefore better equipped than the other residential areas. This is especially true for general practitioners (GPs) and gynecologists, who prefer to settle in these areas rather than underprivileged areas or remote suburbs. This leads to an oversupply of professionals in certain areas and a shortage in others within the region [12]. The effects of segregation on the residents' healthcare have also been widely described in the United States since the 1990s [13], most often from an ethnic and racial perspective, but also, though more rarely, in relation to the structuring, availability and accessibility of health care provision [14]. In France, with rare exceptions, the influence of social segregation and the local supply of health care remains poorly studied on the fine scale of neighborhoods. At the time when the Greater Paris regional health authorities attempted to address the geographical inequalities in the provision of care, it seemed useful to take advantage of the data collected from a representative sample of the Greater Paris population in 2010 to address this issue.

In this study, we were interested in cervical smear screening in the Greater Paris area. The incidence and mortality rates of cervical cancer were estimated at close to 2,800 cases and 1,100 deaths in France in 2015 [15]. Since the 1970s, mortality has decreased considerably, thanks to the large-scale dissemination of cervical screening by way of the smear test. Although about 6 million smear tests are performed annually in France, only 10% of women in the target population (25–65 years of age) adhere to the recommended frequency, which is once every three years after two consecutive negative annual smears. While 40% of women are screened too frequently, 50% are not screened often enough [16]. For this reason, socioterritorial inequalities in cervical screening are interesting to study, not only in themselves, but also, more generally, as a model for other types of opportunistic medical screening. In the Greater Paris area, we previously showed that women who reported that their daily activities were concentrated in their neighborhood of residence had a statistically greater likelihood of not recently having undergone a cervical smear test [17–18]. Furthermore, the characteristics of the neighborhood of residence (e.g., the practitioner density) were more strongly related and statistically significant with delayed smear tests in women who concentrated the vast majority of their daily activities within their residential area than in those who did not [17–18].

The objective of the present paper is to estimate and discuss the statistical associations between attributes of daily frequented neighborhoods and delayed cervical smear tests in the Greater Paris area.

## Methods

# Study design

This study is based on a cross-sectional analysis of data collected in 2010 in the SIRS cohort study, which involved a representative sample of French-speaking adults in the Greater Paris area [17]. The structure and additional details of our database have been detailed in previous studies [1, 17–19].

Women reported the date of their most recent smear test. A delayed smear test was defined as no reported smear test within the three years preceding the survey.

# Study population

Two female subpopulations were studied. The first included all the 1800 women's (N1) who participated in the SIRS survey (after excluding those who had had a hysterectomy; n = 5). The second (subsample of 1800 women's) consisted of the 704 "active and mobile" women (N2), i.e., those for whom the coordinates of their neighborhood of residence, workplace neighborhood, and other frequented neighborhoods different of neighborhood residence and work,were reported. It is the subsample representative of N1 sample.

# Variables

Five individual characteristics were systematically considered: age, level of education, health coverage, living situation, and an indicator measuring the concentration of daily activities in the neighborhood of residence. The women were asked about their participation (total, partial or none) in domestic activities (grocery shopping and running errands, such as to the bank or post office), their social and leisure-time activities (seeing friends, walking, going out to a café or restaurant), and their perceptions of their neighborhood of residence (without a prior definition). A score measuring the concentration of activities in the neighborhood of residence was thus calculated [16]. It ranges from 0 (for women who reported doing all their activities offered outside their neighborhood) to 1 (for women who reported doing all their activities offered within their neighborhood). This score is normally distributed in the study population. As done previously [18–19], we divided the score measuring the concentration of daily activities in the perceived neighborhood of residence into two groups to isolate the respondents whose activity space was highly concentrated within their residential neighborhood (with a score $\geq 0.8$).

# Measures

In addition to their residential address, the participants were asked to indicate the address of their place of employment or studies, and the next most regularly frequented neighborhood. The different "neighborhoods" have been defined as the corresponding IRIS and the adjacent IRIS. Two characteristics of these neighborhoods were studied: (1) the density of general practitioners (GPs) and gynecologists per 100,000 inhabitants (INSEE, BPE 2011) and (2) the mean yearly household income (INSEE, 2011). These two variables were categorized according to the tertiles of their respective distributions in the samples studied. This method was used to distinguish neighborhoods with “low”, “intermediate” and “high” medical density according to the corresponding tertiles (respectively, 44 and 88 GPs and gynecologists combined per 100,000 inhabitants), as well as “poor”, “average” and “wealthy” neighborhoods according to the first and second tertiles for average monthly household income (respectively 15,830 €/CU and 23,332 €/CU).

Two “diversity scores” for frequented neighborhoods were created (one socioeconomic, the other medical density) in order to characterize individuals’ accumulation of potentially risk environmental exposures, regardless of the number of neighborhoods frequented (from 1 [only the residential neighborhood] to the 3 neighborhoods reported in the survey). The purpose of the socioeconomic diversity score was to divide the participants into four groups: those who frequented (i) only poor neighborhoods, (ii) only average neighborhoods, (iii) only wealthy neighborhoods, or (iv), different types of neighborhoods. The medical density diversity score was constructed in the identical manner.

# Statistical methods

For multivariate analyses, two types of regression models were conducted. On the one hand, logistic regression models have been estimated, depending on the case, from the selection Determined a priori of independent variables or at the following your choice of descending variables to remember in the final model according to the procedure advocated by Hosmer and Lemeshow and classically used in epidemiology.

On the other hand, mixed models (or "multilevel models") have been adjusted to account for the hierarchical structure of the data. Simple multilevel logistic regression models, cross-classified multilevel logistic regression models (Fig. 1) were used to simultaneously consider the three types of neighborhoods studied (residential, work or study, visit) for N2 women active and mobile. Finally, associations with socioeconomic and medical diversity scores (adjusted for the same five individual characteristics) were estimated by logistic regression models considering the sampling design. All the analyses were performed using R (library lme4, command glmer) [20].

## Results

The analysis of the 2010 SIRS survey data revealed that a significant proportion of the target population had not been screened for cervical cancer, with 26.9% of the women surveyed reporting that they had not had a smear test in the previous three years.

**TABLE 1. Spatial distribution, median and range of income, and medical density for the different neighborhoods frequented.**

| Neighborhoods | N | Distance (bird's-eye view) from residence[1] | Income of neighborhood population[2] | Medical density[3] |
|---|---|---|---|---|
| Residence | 50 | NA | 17,739 (0-55,513) | 4 (2-7) |
| Work/study | 448 | 6 (0-53) | 9544 (0-62,984) | 4 (1-17) |
| Regularly frequented | 590 | 6 (0-75) | 12,674 (0-67,153) | 3 (1-10) |

[1] km: median (range)

[2] €/CU per year: median (range)

[3] Number of GPs and gynecologists per 100,000 inhabitants: median (range)

On average, the neighborhoods of residence and workplaces of the active participants or students were 7.1 km apart. For one-fourth of this population, the distance was greater than 10 km, and those who worked or studied the furthest from their home were those whose neighborhood of residence was located in the most disadvantaged part of the Greater Paris area: the northern suburbs (**Figure 2**).

Overall, the majority of those who worked or studied did so in a neighborhood of the same socioeconomic type as their neighborhood of residence. Only one-fourth of the workers and students living in a poor neighborhood worked or studied in an average or wealthy neighborhood. Conversely, only 2.1% of the participants living in a wealthy neighborhood worked or studied in a poor neighborhood. **Figure 2** shows the commuting distance of a subsample of SIRS participants: those residing in eight cities in the Greater Paris area.

TABLE 2. Individual and neighborhood of residence characteristics associated with no cervical screening in the previous three years, total population (N1=1800), SIRS, 2010.

| | Late screening | | Model 1 | Model 2 | Model 1+2 |
|---|---|---|---|---|---|
| | % | p | aOR [95% CI] | aOR [95% CI] | aOR [95% CI] |
| **Individual characteristics** | | | | | |
| Age | < .0001 | | | | |
| 18-29 years | 37.0 | | 2.88 [2.04-406] | 2.96 [2.09-419] | 2.89 [2.06-4.07] |
| 30-44 years | 13.1 | | Ref. | Ref. | Ref. |
| 45-59 years | 14.6 | | 1.00 [0.69-1.45] | 0.98 [0.68-1.43] | 1.00 [0.69-1.45] |
| ≥ 60 years | 47.1 | | 3.95 [2.73-5.71] | 376 [2.63-5.37] | 3.95 [2.73-5.71] |
| Living situation | < .0001 | | | | |
| In a couple | 17.3 | | Ref. | Ref. | Ref. |
| Living alone | 42.4 | | 209 [1.66-2.62] | 2.09 [1.66-2.62] | 2.08 [1.66-2.60] |
| Level of education | | | | | |
| Tertiary | 20.1 | | Ref. | Ref. | Ref. |
| Secondary | 32.0 | | 1.90 [1.45-248] | 2.04 [1.55-268] | 1.90 [1.46-2.48] |
| ≤ Primary | 53.4 | | 3.62 [2.23-5.88] | 3.99 [2.45-605] | 3.59 [2.21-5.81] |
| Health coverage | < 0001 | | | | |
| Full coverage | 25.5 | | Ref. | Ref. | Ref. |
| Other | 40.6 | | 1.97 [1.33-2.93] | 2.10 [1.43-3.09] | 2.00 [1.34-3.00] |
| Activity space | < 0001 | | | | |
| Larger than the neighborhood of residence | 24.5 | | Ref. | Ref. | Ref. |
| Limited to the neighborhood of residence | 35.9 | | 1.66 [1.24-2.23] | 1.61 [1.20-2.15] | 1.64 [1.21-2.22] |
| **Neighborhood of residence characteristics** | | | | | |
| Average household income | < .0001 | | | | |
| High (> 23,332) | 23.0 | | Ref. | | Ref. |

| | | | | |
|---|---|---|---|---|
| Moderate (15,830-23,332) | 27.6 | 1.19 [0.82-1.72] | | 1.17 [0.81-1.70] |
| Low (≤ 15,830) | 32.3 | 1.39 [0.97-1.98] | | 1.37 [0.96-1.97] |
| Medical density (per 100,000)[1] | < .0001 | | | |
| High (> 88) | 29.4 | | Ref. | Ref. |
| Intermediate (44-88) | 22.6 | | 1.06 [0.73-155] | 0.77 [0.52-1.12] |
| Low (≤ 44) | 28.7 | | 0.79 [0.53-1.16] | 097 [0.65-1.44] |

[1] General practitioners and gynecologists

In the total study population (N1), the five individual characteristics of interest were significantly associated with a higher risk of a delayed smear test (**Table 2**). The frequency of this delay was higher among the women who lived in poor neighborhoods than among those who lived in wealthy neighborhoods (32.9% versus 23.0%; p < .0001), and lower among the women who resided in neighborhoods with an intermediate medical density (22.6%) than among those residing in neighborhoods with low or high medical density (respectively, 28.7% and 29.4%; p < .0001). Nonetheless, after adjusting for individual characteristics, neither the income level of the neighborhood of residence (even if the strengths of the associations were similar) nor its density of GPs and gynecologists were significantly associated with a delayed smear test, whether these two characteristics were considered separately or together in the models.

**TABLE 3 Characteristics of the three types of neighborhoods (residential, work/study, and the third most regularly frequented) associated with no cervical screening within the previous three years in the active and mobile population (N2=704), SIRS, 2010**

| | N | % | Model 1<br>aOR[1] [95% CI] | Model 1+2<br>aOR[1] [95% CI] | Model 1+3<br>aOR[1] [95% CI] | Model 1+2+3<br>aOR[1] [95% CI] |
|---|---|---|---|---|---|---|
| **Neighborhood of residence** Average household income | | | | | | |
| High (> 23,332) | 297 | 16.4 | Ref. | Ref. | Ref. | Ref. |
| Moderate (15,830-23,332) | 731 | 40.3 | 1.63 [0.86-3.10] | 1.51 [0.78-2.90] | 1.60 [0.84-3.06] | 1.49 [0.77-2.87] |
| Low (≤ 15,830) | 786 | 43.3 | 2.95 [1.48-5.90] | 2.60 [1.27-5.32] | 2.70 [1.33-5.47] | 2.38 [1.15-4.93] |
| Medical density (per 100,000)[2] | | | | | | |
| High (> 88) | 591 | 32.6 | Ref. | Ref | Ref. | Ref. |
| Intermediate (44-88) | 633 | 34.9 | 0.74 [0.39-1.39] | 0.77 [0.41-1.45] | 0.80 [0.46-1.64] | 0.83 [0.45-1.55] |
| Low (≤ 44) | 590 | 32.5 | 0.78 [0.41-1.49] | 0.85 [0.45-1.62] | 0.87 [0.46-1.64] | 0.93 [0.49-1.76] |
| **Neighborhood of work/study** | | | | | | |
| Average household income | | | | | | |
| High (> 23,332) | 191 | 19.3 | | Ref. | | Ref. |
| Moderate (15,830-23,332) | 448 | 45.3 | | 1.24 [0.68-2.27] | | 1.16 [0.63-2.13] |
| Low (≤ 15,830) | 350 | 35.4 | | 1.72 [0.86-3.43] | | 1.65 [0.82-3.32] |
| Medical density (per 100,000)[2] | | | | | | |
| High (> 88) | 336 | 34.0 | | Ref. | | Ref. |
| Intermediate (44-88) | 385 | 38.9 | | 0.62 [0.35-1.09] | | 0.66 [0.37-1.17] |
| Low (≤ 44) | 282 | 28.5 | | 0.45 [0.24-0.84] | | 0.54 [0.27-1.08] |

| | | | | |
|---|---|---|---|---|
| **Neighborhood regularly frequented** | | | | |
| Average household income | | | | |
| High (> 23,332) | 423 | 38.2 | Ref. | Ref. |
| Moderate (15,830-23,332) | 451 | 40.7 | 1.99 [1.11-3.57] | 1.93 [1.07-3.47] |
| Low (≤ 15,830) | 234 | 21.1 | 2.18 [1.15-4.14] | 2.10 [1.10-3.99] |
| Medical density (per 100,000)[2] | | | | |
| High (> 88) | 367 | 33.1 | Ref. | Ref. |
| Moderate (44-88) | 418 | 37.7 | 0.61 [0.34-1.09] | 0.46 [0.24-0.87] |
| Low (≤ 44) | 346 | 31.2 | 0.45 [0.24-0.84] | 0.64 [0.36-1.14] |

[1] Adjusted for age, living situation, health coverage and level of education

[2] General practitioners and gynecologists

Considering only the women in the N2 subpopulation (active and mobile), 16.1% had not undergone a smear test in the previous three years. Table 3 shows a significantly higher risk of a delayed smear test among those in poorer neighborhoods, whether it was the neighborhood of residence or the frequented neighborhood (and the same trend was found, although not significant, for the workplace neighborhood). The strengths of the associations were relatively stable across the models, even if part of the “effect” of neighborhood poverty decreased when other neighborhoods were included in the models, with a 19% decrease in the adjusted odds ratio (aOR) from Model 1 to the full model (Models 1 + 2 + 3).

The results were less clear with regard to the density of medical services. Indeed, the medical density in the neighborhoods (residential, work and frequented) was not significantly associated with a delayed smear test, except in the full model (**Table 3**, Models 1 + 2 + 3). In the full model, reporting frequented neighborhoods with an intermediate medical density appeared to protect against the risk of a delayed smear test (aOR = 0.46; 95% CI = [0.24-0.87]). Although not significant, the associations are similar for the density of medical services in the workplace neighborhood: working in an intermediate-density or (especially) a low-density neighborhood was associated with a lower risk of a delayed smear test.

**TABLE 4 Association between the two diversity scores for multiple neighborhoods frequented and no cervical screening within the previous three years in the total study population (N1 = 1800), SIRS, 2010**

| | | Model 1 | Model 1+2 | Model 1+2 |
|---|---|---|---|---|
| | Nb | aOR[1] [95% CI] | aOR[1] [95% CI] | aOR[1] [95% CI] |
| **Income** | | | | |
| High-income neighborhoods only | 1079 | Ref. | | Ref. |
| All the neighborhoods combined | 171 | 1.01 [0.63-1.62] | | 0.79 [0.50-1.24] |
| Middle-income neighborhoods only | 232 | 0.85 [0.57-1.27] | | 1.10 [0.77-1.59] |
| Low-income neighborhoods only | 319 | 1.68 [1.06-2.67] | | 1.59 [1.15-2.20] |
| **Medical density[2]** | | | | |
| High-density neighborhoods only | 1040 | | Ref. | Ref. |
| All the neighborhoods combined | 264 | | 1.38 [0.96-1.97] | 1.45 [1.02-2.07] |
| Intermediate-density neighborhoods only | 265 | | 1.22 [0.86-1.73] | 1.27 [0.90-1.78] |
| Low-density neighborhoods only | 231 | | 1.47 [1.05-2.07] | 1.53 [1.09-2.14] |

[1] Adjusted for age, living situation, health coverage and level of education

[2] General practitioners and gynecologists

In the total study population (N1), after adjusting for the five individual characteristics, there was a significant association between the socioeconomic and medical diversity scores for the multiple neighborhoods frequented and the risk of a delayed smear test (**Table 4**). All the situations that did not include frequenting only neighborhoods with a high density of medical services were associated with a significantly higher risk of not having had a smear test in the previous three years. Also in the same model, the women who only frequented poor neighborhoods had a significantly higher risk of a delayed test than those who only frequented wealthy ones.

# Discussion

The individual factors associated with delayed cervical screening were relatively similar to those previously analyzed [17]. It is significantly more common for the most recent smear test to date back further than the past three years among women with the following characteristics: younger, older, single, a low-level of education, and without complementary health insurance. In France, at the time of the survey,

cervical cancer screening was considered opportunistic screening, which means that it was not completely covered by basic Social Security. In 2010, a free, organized screening experiment [21] was implemented in 13 pilot departments in metropolitan France, but none of them was involved in the SIRS study. The nationwide deployment of this free, organized cervical cancer screening is slated for 2019. As previously reported in the 2010 SIRS data [17], daily activities limited to one's neighborhood of residence appear to be significantly associated with a risk of delayed screening, other things being equal. For the first time, using a representative sample of the adult population of the Greater Paris area, we show here that being cumulatively exposed to poverty or to a limited supply of healthcare services is associated with a higher risk of a delayed smear test. Only one other study that examines such accumulations (or disparities) between frequented neighborhoods was found. It concerns a population in Los Angeles County. That study showed that individuals who live, work, shop, worship and seek healthcare in disadvantaged neighborhoods were more likely to perceive themselves as being in poor or fair health. Interestingly, it also showed that people might use their own status – or their own neighborhood of residence – as a reference point of comparison [22]. This suggests that there are both pros and cons to using external, objective measures of neighborhood poverty.

The strengths of our study include having used a representative population, constructed a cumulative score for multiple exposures according to frequented spaces, and explored two types of neighborhood characteristics that correspond to different mechanisms of action [23]: medical density, which concerns the availability and accessibility to care [24], and average household income, which concerns various psychosocial mechanisms (social interactions, health literacy, shared standards, knowledge, attitudes and health practices).

There are a number of limitations that should be addressed. First, only a few frequented neighborhoods were surveyed (up to three). In a future survey in 2020, we plan to include up to six regularly frequented neighborhoods in addition to the neighborhoods of residence and work. Second, neighborhood characterization could be improved by using more detailed care supply data (in particular, accounting for part-time practitioners and for doctors who receive Social Security-approved fees or, conversely, those who charge additional fees) and/or by regrouping neighborhoods using social indicators other than the residents' median income (for example, considering the proportion of the population that is unemployed and/or inactive, or the proportion of immigrants). Also, people who frequent a given neighborhood during the day may have very different social profiles than those of its residents, especially in the districts where there are various activities, shops or services [25]. Finally, the delimitation used to define neighborhoods in this study (the IRIS of destination and its adjacent IRISs) may be discussed. Although previous analyses of the same data showed that the effects of the characteristics of the neighborhoods of residence were at a best approximation at this spatial scale [18], there is no evidence that this is true for the other frequented neighborhoods.

Despite these limitations, a cumulative exposure score, such as the one we have constructed, may be a relevant approach for analyzing the effect of frequented areas. When taking into account even a limited number of frequented areas with a simple questionnaire (three in our case), the results of our regression

models show that modeling every frequented neighborhood simultaneously requires large populations (or large sample sizes) to be sufficiently powerful (not to mention having to increase the number of models for different subpopulations). Also, the underlying assumption in these models – i.e., that the tested exposures are independent of each other – is largely false. Therefore, even more power is required to test interactions. Real-time geolocation data (e.g. those acquired by GPS sensors in smartphones) permit a detailed description for activity spaces for equipped individuals [26], but the complexity of these analyses [27-30] calls for a simplified approach for public health studies. Furthermore, even though some authors (for example, [26]), precisely described how the spatial and temporal dimensions of such spaces can be used to interpret public health activity, the methods used for this analysis are still unclear. An alternative use for a cumulative score like ours may be to estimate the outlines of the activity spaces and to examine their general or average characteristics [31], but in so doing, we may lose the ability to characterize frequented areas on a fine scale. Indeed, because of the diverse neighborhoods in the Greater Paris area, the expansion of an activity space would include very disparate neighborhoods, such as a poor residential area and a workplace in a well-off, historical area of Paris.

# Conclusions

In this study, we showed that women who live and work in poor neighborhoods and whose next most regularly frequented neighborhood was also poor were at significantly higher risk for late cervical cancer screening. A cumulative exposure score, such as the one presented here, may be a relevant approach for analyzing this effect.

The lack of consideration of nonresidential spaces is criticized as constituting a "local trap", which results in an incomplete estimate of daily environmental exposure regarding a given population's activity spaces [4, 26]. This seems particularly problematic in cities like Greater Paris, which consists of segregated residential spaces, uninhabited activity spaces (notably tertiary) and daily urban migration (whose distance is socially determined: in Paris, those employed and from a low social class tend to have a longer daily commute). Conversely, research on the consideration of activity spaces has increased significantly in public health literature, but it still raises complex questions on how the detailed characterization and analysis of these spaces can be evaluated.

# Abbreviations

BPE Base Permanente des Equipements (Permanent Facilities Database)

GPs General practitioners

INSEE Institut National de la Statistique et des Etudes Economiques (National Institute of Statistics and Economic Studies)

IRIS Îlots Regroupés pour l'Information Statistique (aggregated units for statistical information)

OR: Odds ratio

SIRS Santé Inégalités et Ruptures Sociales (Health, inequalities and social disruptions)

# Declarations

### Ethics approval and consent to participate

### Ethics approval

The SIRS cohort study was approved by the French privacy and personal data protection authority, CNIL (Commission Nationale de l'Informatique et des Libertés).

### Consent to participate

All the participants provided informed consent before being enrolled in the SIRS cohort study. Verbal consent was obtained and approved by the CNIL.

### Consent to publish

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

### Availability of data and materials

The data are confidential (contact person: Dr. Pierre CHAUVIN, pierre.chauvin@inserm.fr)

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### Authors' contributions

MT: Performed literature search, data extraction, and data analysis; drafted the manuscript; and incorporated comments for the final version of the manuscript.

JV: Contributed to the conceptualization and design of the study, gave advice for interpreting the results, and reviewed the manuscript.

PC: Oversaw conceptualization and design of the study, provided advice for data analysis and interpreting the results, and reviewed the manuscript.

All the authors approved the final manuscript.

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# Figures

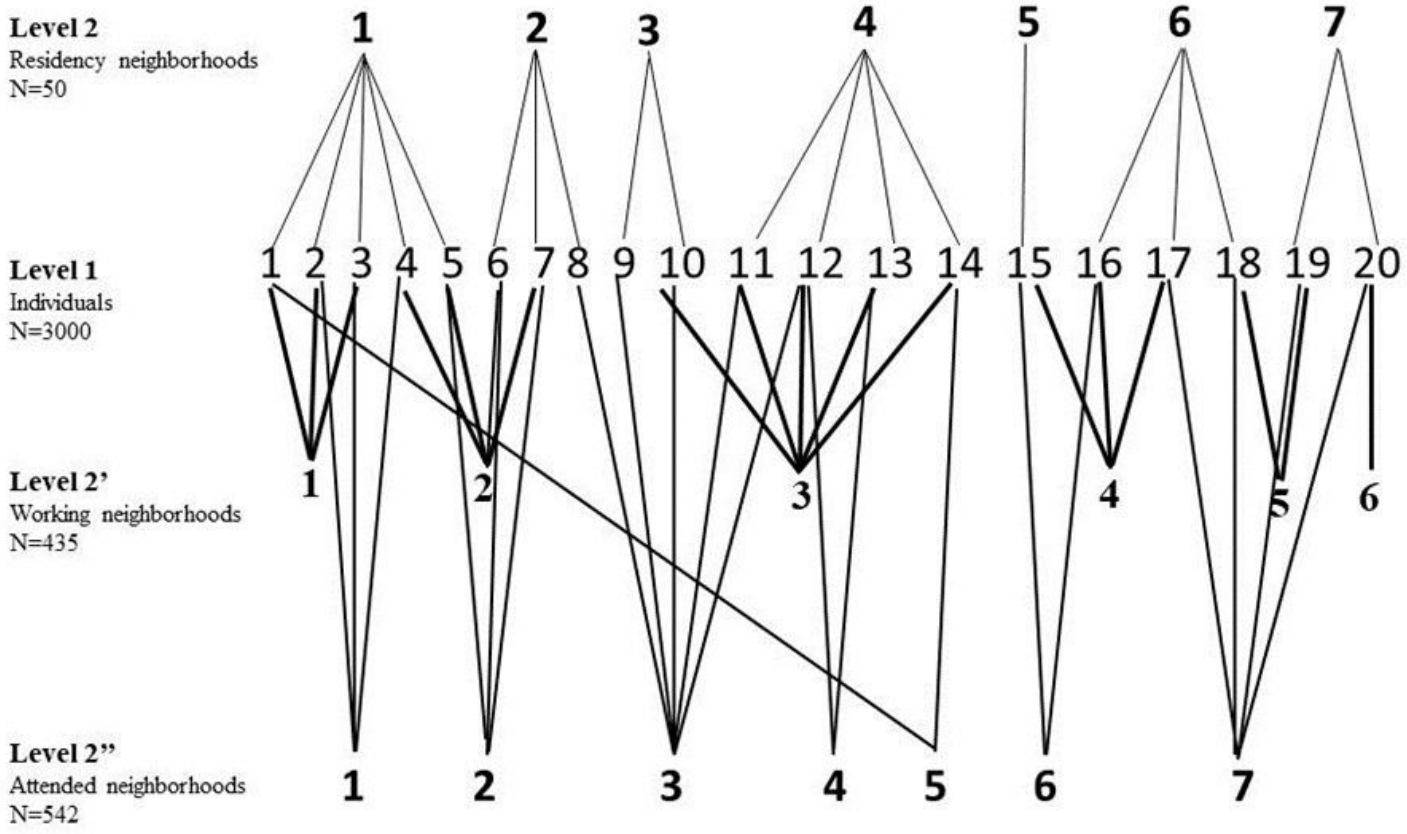
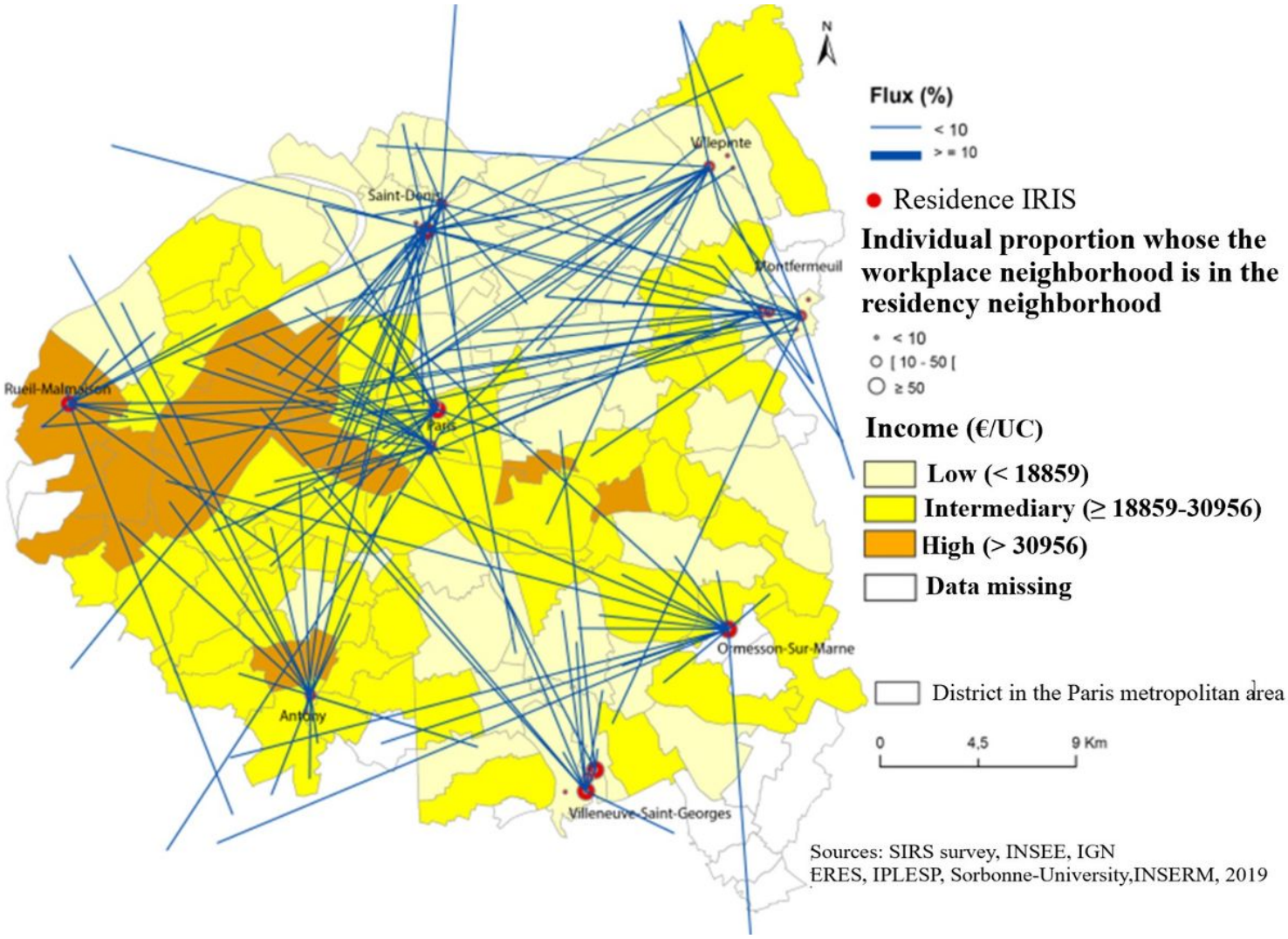



**Figure 1**

Cross-classified multilevel logistic models This figure shows a cross-classification. Level 1 refers to the 3,000 individuals who can reside in the 50 IRISs, work in 435 locations and frequent 532 locations. In this

example, it is seen that individuals 1 to 3 have the same neighborhood of residence and work , but that they do not frequent the same neighborhood.




## Figure 2

Spatial trajectories from the neighborhood of residence to the neighborhood of work/study: investigation of eight different cities within the Greater Paris area (SIRS, 2010). The lines represent the proportion of the individuals' mobility. The dots concern a few individuals in the SIRS cohort. Their size depends on the proportion of individuals whose neighborhood of work is in the neighborhood of residence. The color represents the distribution of income in the different districts of the Paris area.