Behind the use of medical facilities, the influence of subjective geographic proximity: a quantitative measuring

Alexis Pokrovsky - Cnam LIRSA EA4603

alexis.pokrovsky@lecnam.net

Romain Aeberhardt – Veltys

raeberhardt@veltys.com

Sandra Charreire Petit - Université Paris-Saclay, RITM

sandra.charreire-petit@universite-paris-saclay.fr

Damien Talbot - UCA – IAE Clermont Auvergne, CleRMA

damien.talbot@uca.fr

Abstract:

The recent interest in Organization Studies towards spatial issues tends to neglect analyzing users, consumers or citizens experiences of proximity. Focusing on this perspective helps to better adapt organizations to their expectations as well as actual or future practices. Our paper addresses this gap by analyzing how inhabitants in an urban area experience proximity to reach the hospital when they have the choice between two similar facilities located at similar distance. Quantifying individual patterns in a situation of comparable choice offers the opportunity to measure the relevant variables that ultimately play a role in users daily experience of proximity. Our research is based on a real case exploiting mass data in an urban area. We reveal that subjective proximity depends from two main variables: poverty conditions and the boundaries defining people's activities. This research provides managerial contributions in the field of health economy as well as theoretical contributions on the extent to which space matters for users in public activities, revisiting the role of proximities, between subjectivity, contexts and boundaries.

Keywords: Space matter, Health, Proximity, Context, Subjectivity

INTRODUCTION

Medical resources location decisions usually face spatial dilemmas : is it better to favor the implementation of large specialized platforms in major urban centers or to ensure the preservation of a proximity-based medicine through geographic dissemination of the units? The first solution provides advanced state of the art technical expertise through concentration of resources, while the second option ensures larger access to a medical service for a greater portion of the population, especially in remote areas.

One way to contribute to this debate is to investigate in depth the spatial behaviors of health service users, in order to measure the various variables associated with distance, proximity and health issues. This type of approach has been conducted by the School of Proximity over the last 25 years, mixing researchers from various academic fields (Bellet et al., 1993 ; Torre et Rallet (2005) ; Boschma (2005) ; Boschma et Frenken, 2010 ; Torre et Talbot, 2018). For these scholars, "proximity" as a notion encompasses the many questions that distance imposes on the interactions of agents in their various activities. In other terms, if distance plays an inhibiting role on agents' interactions, it still can be overpassed or "managed" by proximity, defined here as one of the potential modalities or arrangement of distance (Lussault, 2007). As such proximity generates positive or negative effects on interactions between agents and organizations, depending on the possibilities offered for assembling or combination in the context where it occurs. The initial works of this academic school have been focusing on the objective aspect of proximity, being understood as a measurable and acceptable description of proximity, while the subjective aspect, being the intimate or self-constructed evaluation of distance by agents or organizations was kept aside or relatively unexplored. Basically, an objective measuring of proximity would refer to a standard metric distance while a subjective measuring would interrogate each individual construction on "how close" each one stands from another point. Recent researches in this academic field are now turning to a more "cognitive" description of proximity (Aguilera, Lethiais et Rallet, 2015), providing an orthogonal view to objective proximity. By cognitive the authors refer to the set of perceptions, scripts or heuristics mobilized when people set a judgement on the closeness to a person or an object. This means that agents combine an objective reading of proximity with a more individual and subjective perception of proximity when they make a decision or a judgment on an object or a situation. In this perspective the above-mentioned issue of measuring the effects of distance on health facilities raises the question of objective versus subjective dimension of proximity on their

frequentation : is metric distance the main variable explaining agents' behaviors or are other subjective variables influence the perception of proximity ? This question has important consequences for decision of location of medical facilities such as hospitals. The purpose of our paper is precisely to answer the following question : How do individuals concretely deal with proximity in their decisions regarding the frequentation of a hospital structure, when they are in a situation of equivalent distance for comparable units? We develop in our paper a comprehensive statistical model that contributes two ways : the first contribution is to bring practical and actionable answers on the debate about the spatial distribution of medical resources, while the second contribution is to bring a methodological improvement on the measurement of this notion of subjective proximity.

Our research thus proposes to address this issue by analyzing mass data provided in a single case study with an econometric regression model. The case we study offers the opportunity to measure spatial behavior patterns of the total population of an urban area, representing approximately 725 000 inhabitants. The behavior we are scrutinizing in our research relates to the selection between two hospitals for patients that are located at a similar distance between those two large hospitals in an urban area densely equipped with roads and transport means. If situated at similar distance, is there a variation in the selection of one or the other hospital that would reveal a form of difference of perception of proximity?

Our paper is divided in four sections. In the first part, we will review the notion of subjective proximity, with a focus on health-related literature. The second part will be dedicated to the case study and the methodological approach. The third part will report the summarized results. In the final part we will discuss our results.

1. THEORETICAL FRAMEWORK

1.1. SUBJECTIVE PROXIMITY

In the economic geography of the 90's most of the research questions were focused on finding the "right" distance and/or the right location between organization, "rightness" being evaluated under the lens of costs and externalities (Fujita & Krugman, 1995; Krugman, 2000). The new approaches on spatiality are more influenced by the New Economic Sociology stream, for which social reality is constructed, and apparently "objective" notions or concepts are actually modelled by recursive actions (Dale, 2005).

One of the key notions in this interplay is the centered around the keyword of proximity. Proximity is a notion mobilizing non-geographic terms that describes (i) to which extent there is "nearness" between organizations or actors, and (ii) what outcome the different dimensions of proximity may bring to interaction (Torre & Talbot, 2018). Indeed, scholars of the school of proximity have identified so far five dimensions of proximity, each of those having a distinct influence on the level and nature of interaction (Boschma, 2005). Proximity not only creates the conditions for interactions ; it also provides a predictor of the type and nature of interactions depending on which dimensions of proximity is activated (Grossetti & Filippi, 2004). The five iconic dimensions of proximity are geographic, organized, cognitive, social and institutional (Boschma, 2005) and these five dimensions are those that are the most mobilized by researchers due to a great operationalization level.

Of course, proximity still relies on objective facts, like reduced distance of various nature : small kilometric distance between two cities for instance, of small cognitive distance in terms of knowledge between two individuals. But it is not only limited to that objective nature. When discussing about proximity, we tend to consider a dyad formed between two units of analysis (organizations, people, places…), proximity being the in-between of this dyad. Focusing on subjective proximity requires to position at the level of one of the units of the dyad (like a person) and investigate on the assessment he/she sets of his/her closeness to the other part of the dyad, whether it is openly formulated or not. In the paper from Cariou, Ferru and Rallet (2018) the authors analyze how a judgement is made by artists on their proximity with some key creative places: their subjective proximity is thus built combining the distinctive meanings that they attribute to each creative place with their own artistic projects or intention. Proximity is thus based on a small distance, but in the meantime incorporates a perception of that small distance by actors, inducing a subjective dimension. As such, proximity is about interpreting the nearness that separates agents.

Health management actually provides a crucial area of research on the cognitive dimension of proximity. Medical practices are embedded in a space that is not necessarily at the same scale than other type of spaces (like consumption, work or social spaces). The fact that medical practices touch our most intimate representations has undoubtedly a major influence on our representations of space. Therefore, it is highly likely that in this particular area, the sense of nearness, or proximity is different, and that our capacity to represent how close we are from

something or someone is altered by subjective factors. This is the case for geographical dimension of proximity.

1.2. Subjective Geographic Proximity

Geographic proximity is defined as a distance between objects or people, pondered by the economic sacrifice and time necessary to overcome it (Rallet & Torre, 2004; Torre & Rallet, 2005). We will focus our case on exploring deeper this notion of geographic proximity, in particular through the notion of subjective geographic proximity, a topic that is attracting renewed interest from the research community (Cariou, Ferru, & Rallet, 2018).

In the case of health issues, the level of medical condition or level of criticality will deeply alter the judgement on geographic proximity. Indeed, the medical context will influence geographic proximity: the more important the condition, the longer the distance one is willing to cross. In a comparison of three different approaches of measuring an individual's activity across space, the authors highlight the plasticity of space based on context, confirming that area definitions are dynamic and fluid, depending on cognitive representations (Rainham, McDowell, Krewski, & Sawada, 2010). In a research on the use of abortion facilities in California, it has been demonstrated that rural women who have fewer access to public funded abortion care centers travel longer distance than urban women, thus achieving similar rate of abortion than urban women (Johns, Foster, & Upadhyay, 2017). This result illustrates that it is not because care facilities are not homogeneously located that individual tend to reduce their expectation for medical care. Distance in this instance is not judged as a physical barrier when there is the intention to ensure consistent medical care for an important health matter.

Distance is usually envisioned as the Euclidean measurement between two separated location. In our case discussing health issues, it could be the physical distance between a patient's home and any health facility location. This measure may be linear (straight distance) or via networks (such as public transports, roads). The basis of measurement are spatial metrics such as Euclidean distance (or straight line), roads or streets (or networks), and eventually Manhattan distance or Minkowski distance[1].

However, the definition given of geographic proximity complements this notion of physical distance with a first level of socio-economic assessment, which are the resource necessary to

[1] The Manhattan distance is associated to the Euclidean measure under the Pythagorean theorem. Minkowski distance is a combination of linear and Manhattan distance.

sacrifice in order to overcome the distance associated with it (Torre & Rallet, 2005). It gives a primary importance to the contextual socio-economic factors that builds the judgement on distance. Indeed, subjective geographic proximity will not only be built on various spatial metrics (Euclidean, networks, Manhattan, Minkowski) it will also integrate the judgement that an agent has on its physical and economical condition to overcome that distance (Lussault, 2007).

A third category enters in the construction of the subjective geographic proximity, being time. In some occasions, time reveals to be a better metric than Euclidean distance to formulate a judgement on distance. In the case of remote areas, the one- hour range has been accepted as the critical proximity measurement criteria for severe medical conditions, such as palliative care. The main reason is that one hour also known as the "golden hour" has a strong influence on to the life expectancy in emergency coverage (Cinnamon, Schuurman, & Crooks, 2008).

Subjective proximity can therefore be seen as the combination between economic, social and institutional factors and their interference in the judgement about distance or its representations, such as frontiers, travel costs or time. An illustration of this process of subjective proximity where physical distance is aggregated with transportation means or resources and a time constraint is given in the research paper analyzing access to General Practitioner Offices (GPO) in urban areas (Graham, 2018). In this case, the "accepted range" of subjective geographic proximity to visit a GPO will be defined by walking distance or time (1,5 km or 20 minutes' walk).

Hence, we will select the following variables to measure subjective geographic proximity in our case study as shown in table 1.

Table 1 : Summary of variables

Component of geographic proximity	**Variable selected**	**Unit of measure**
Physical distance	Linear distance (radial)	km
Physical distance per road network	Driving distance	km
Time distance per road network	Driving time	minutes
Time distance per public network	Transit time	minutes
Socio economic factor	Social fragility index	Index

Our paper aims at analyzing spatial behaviors of patients going to a hospital. To do so, we investigate the case of two hospitals in the suburban area of Paris that offer a similar or equivalent set of medical services in a densely populated area. The choice to go to one or the other hospital for an individual is a complex decision that is the result of many combined factors: our study focuses on the result of the interplay of those factors which is ultimately the decision taken to go to one or the other hospital for each patient, for which we compute the flexibility in the decision tree (or said differently the underlying probability for him to go to one or the other hospital). We assume that the physical distance that separates the two hospitals should constitute one of the primary factors driving this choice. We thus study how the choice by the patients depends from the distance between their house and the care facility. Referring to the proximity school, we then integrate in our statistical model elements of social factors which have been clearly demonstrated to influence the judgement on proximity and spatial behavior. The fact to use distance as a primary variable enables to measure its effect in the decision, but also to control its impact when we measure additional variable effects, such as the frontier effect, or the socio-economic factor. By doing so, we stand in a position to identify the role of the two additional variables in the construction of the perception of distance and compare their magnitude to the weight of objective distance which observation seemed natural in the first place. We may assume that the choice to go to one hospital only depends from distance and that the frontier is only an administrative construct with no influence on the decision tree. We will on the contrary observe how these social and institutional variables impact the choice of frequentation of one or the other hospital, even when we have neutralized the effect of distance. These empirical results highlight a singularity in the behavior that supersedes objective grounds and finds its rationalization with the notion of individual perception of proximity.

2. METHODOLOGY

2.1 CASE DESCRIPTION

In France, over the recent years, regional health authorities (“Agences Régionales de Santé”, or ARS) are working to rationalize the offer of health services over territories. Their main purpose is to ensure a better coverage for medical care in low medical resource density areas while reducing overlaps in highly equipped areas. Therefore, the ARS are working to redesign the allocation of publicly funded medical facilities, among which large university hospitals, in line

with expected changes in population settings. This process is labelled in France as "Groupement Hospitalier de Territoires" or GHT. GHT is a process by which hospital facilities distribution is redesigned at a territory level following population needs or constraints to ensure smoother coverage.

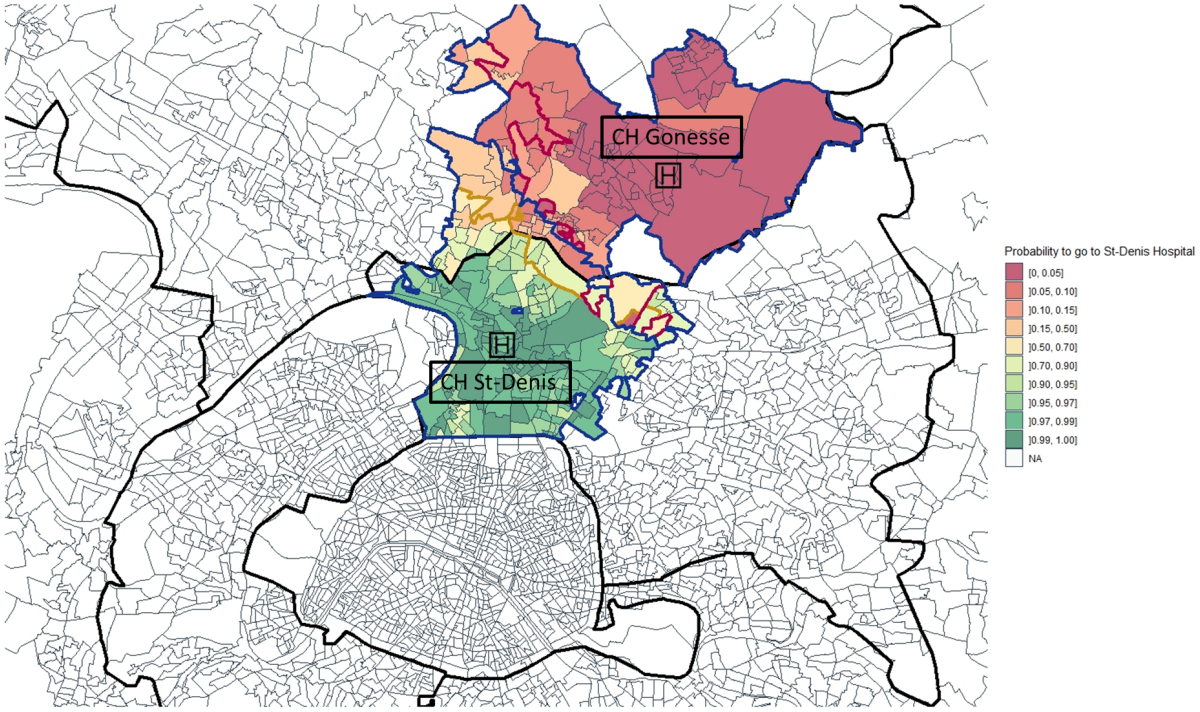
Our case is embedded in this process and deals with the organization of a GHT in the northern part of the Great Paris Metropolitan area (GMP). The map illustrated in figure 1 pictures the Paris Metropolitan area and the location of two major hospitals located in the north east suburban area of the GMP: Seine Saint Denis and Val d'Oise. Our field of study concerns the GHT entitled "Plaine de France" which is composed of the two CH mentioned in the map as CH Gonesse and CH Saint Denis, which we will later refer to as Gonesse and Saint Denis. This GHT Plaine de France has been created in and could be compared to a "merger of the equals". Both hospitals provide similar service "proximity" offer as per the documentation providing the basis of the mutual agreement[2].

The number of hospital practitioners is equivalent between the two hospitals (129 for Saint Denis and 125 for Gonesse). Even though a few differences exist between the two hospitals the service offer structures are very similar. However, our main assumption does not rely on proving the perfect equivalence of services. What is important is that none of the hospitals are polarized toward specific pathologies for each of the districts. For instance, if the CH Saint Denis was specialized in cancer treatment for lungs, and there were more smokers in Seine Saint Denis, it would of course change the factors for decisions. The only differences in service between the two hospitals we can observe are minimal and the population between the two departments share the same descriptors in terms of pathologies. Therefore, we can assume that:

A) Each hospital exercises a certain attraction on the inhabitants of each department, this attraction being mainly due to the effect of distance;
B) Once the difference in distance is taken into account, there is no reason for patients to select the hospital in their district, unless such a choice reflects a distortion in the perceived proximity, such distortion being dependent to the level of social fragility.

[2] Available at : https://www.iledefrance.ars.sante.fr/sites/default/files/2017-05/CONVENTION_GHT_PLAINE_DE_FRANCE.pdf

Figure 1: map of the Paris Metropolitan area and location of the two hospitals in the case study. Source: Veltys



2.2 DATA COLLECTION

The data come from various sources to match to the variables identified in table 1. We compiled venues to each hospital, Gonesse and Saint Denis, from the hospitals' administrative information systems. Patients' addresses were geocoded to find their household's IRIS.

This enabled us to then define what portion of the IRIS population visited what hospital. Our sample concentrates on the area around Gonesse's hospital and Saint Denis's hospital. It covers 284 IRIS representing about 725,000 persons, which corresponds to one fourth of the total population of Seine-Saint-Denis and Val-d'Oise districts. Statistical methods for analyzing population ecology usually computes data gathered within the administrative units composed by cities or districts (in France the smallest administrative unit gathering census data is the *commune*). In the case of densely populated territories as in our case, a commune may not provide robust results. Indeed, the amount of population per *commune* varies from a few hundred to over 50 000 habitants, making thus comparison of results between units statistically difficult or biased. The French statistical body (INSEE) has therefore developed a new unit of measure under the acronym IRIS, which represents a sub-unit of the commune with a

population ranging from 1800 to 5000 inhabitants, making it therefore a more comparable unit for robust statistical analysis. The choice of this unit of analysis prevents from falling into spatial statistic traps identified by many researches.

Information about the individual's frequentation of a hospital are only available at the IRIS level. This is one of the methodological innovations of this research. Indeed, in France individual health or social data collection for public data treatment is not allowed to ensure the protection of intimacy and to prevent private, commercial use or discrimination from third parties. Gathering the data at the IRIS level is a methodological improvement since the crossing of IRIS with other public data provides a level of information that ensures protection of individual intimacy while ensuring sufficient granularity for statistic relevance. The fact to use IRIS as the unit of analysis has one major drawback, which is to reduce the number of observations or the size of the sample and to limit the number of control variables used in the analysis. To this end we selected the poverty index which has proven to be robust at the IRIS level. This reduction of dimensions limits the overfitting and increases the statistic power.

Administrative data at the IRIS level come from open data (mostly the Census) and have been used to compute the social fragility index. This index is built around eleven variables: median revenue, share of social allowance beneficiaries (RSA, dwelling, CMUC, single parents, share of beneficiaries covered at more than 50%), share of taxpaying households, unemployment rates (global, youth, long term, unqualified).

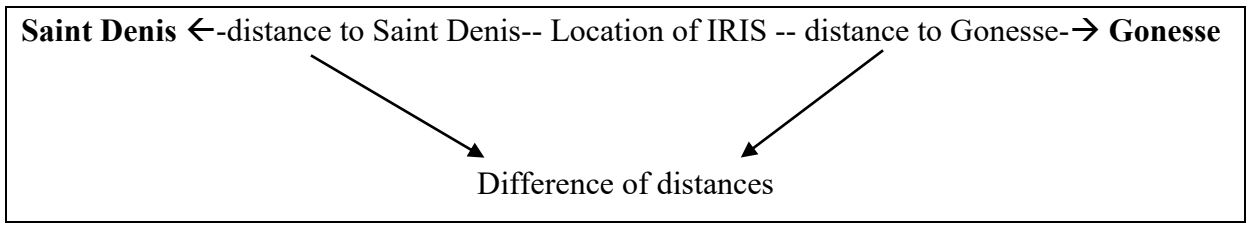
Finally, distances were computed using various APIs[3], and in particular the one from google maps. It allows to compute the different distances and travel times between each IRIS and both hospitals studied.

2.3 STATISTIC MODEL

The data we compute for assessing proximity is not the distance between an IRIS and a hospital, it is **a difference of distance metric** (or respectively difference in time metric), reflecting at best the notion of proximity from the user's perspective. For each IRIS we collect the distance to Saint Denis and the distance to Gonesse as illustrated in figure 2 and calculate the difference between the two values under the formula: Distance to Saint Denis minus Distance to Gonesse.

[3] An API is an application programming interface providing geo coding data

Figure 2: Explanation of the difference of distances



Hence, if distance to Saint Denis is greater than distance to Gonesse, then the variable shows a positive sign. If the sign is negative, then this means that the distance for an individual in an IRIS to go to Gonesse is greater than the distance to go to Saint Denis. This variable is expressed in 1000 meters for distance in car (transport by road) or straight line (radial distance). The time-based difference of distance has been measured in minutes.

Table 2 provides descriptive statistics of our sample. The average time difference between Saint Denis and Gonesse is -2,67 minutes, meaning that the average time distance from the IRIS sample is slightly closer to Saint Denis. The average deprivation index is of 17,30 meaning that the IRIS in average are just below the mid value of 15 in social fragility index.

Table 2: descriptive statistics

	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Population	284	2,549	971.08	0	2,026	3,006	6,912
Social fragility	284	0.17	0.11	−0.19	0.10	0.26	0.30
Δ Driving time (min)	284	−2.69	11.09	−23	−12	7	18
Δ Driving distance (km)	284	−4.43	9.50	−25	−9	0	17
Δ Radial distance (km)	284	−2.50	5.10	−9	−7	1	9
Δ Transit time (min)	284	−28.11	21.94	−65.90	−42.67	−17.80	64.25

The data at hand allows us to know which hospital was chosen by each patient. The goal is then to understand why and in particular to see :

1) whether the district boundary has an impact on this choice, and quantify it
2) whether this effect is homogeneous across patients or if it depends on their fragility

Of course, these effects need to be measured once the difference of distances with respect to each hospital has been taken into account.

The econometric situation may look quite standard at first sight, but it requires extra care in its specifications and interpretations due to the symmetrical situation between both hospitals (if

one is chosen, the other is not ; when the difference in distances increases for one hospital, it is reduced for the other one).

We first present the most general model which is more natural but lacks statistical power and then we explain how we transform it into a simpler and more parsimonious model.

We try to model the probability to choose one hospital among two given three covariates : the district of residence, the difference of distances with respect to each hospital and the Fragility index. The most general model consists of estimating, for each district, the effects of distance, fragility and their interaction.

For patients living in the Seine-Saint-Denis district, the individual choice model corresponds to the following.

$$P(y_i = 1|\Delta d_1, F, district = SSD) = \alpha_1 + \beta_1 \Delta d_1 + \gamma_1 F + \delta_1 F \Delta d_1$$

Where $y_i = 1$ if the patient goes to the Saint-Denis Hospital, $\Delta d_1$is the difference in the distances with respect to each hospital and F is the fragility index.

More precisely,

$$\Delta d_1 = dist(patient_i, Saint - Denis\ Hospital) - dist(patient_i, Gonesse\ Hospital).$$

Similarly, for patients living in the district of Val d'Oise, the model is the following:

$$P(y_i = 0|\Delta d_0, F, district = VD) = \alpha_0 + \beta_0 \Delta d_0 + \gamma_O F + \delta_0 F \Delta d_0$$

For reasons of symmetry, this time the model uses $\Delta d_0 = -\Delta \mathrm{d}_1$.

These models can be evaluated separately on the patients of Seine-Saint-Denis and on the ones of Val-d'Oise, or we can run a global estimation on the pooled dataset. For this latter estimation, we need to harmonize the data using the fact that

$$P(y_i = 0|\Delta d_0, F, district = VD) = 1 - P(y_i = 1|\Delta d_0, F, district = VD).$$

The pooled model can be written as:

$$P(y_i = 1|\Delta d_1, F, district = SSD) = 1_{SSD}\,[\alpha_1 + \beta_1 \Delta d_1 + \gamma_1 F + \delta_1 F \Delta d_1] + 1_{VD}\,[\tilde{\alpha}_0 + \beta_0 \Delta d_1 + \gamma_0 \tilde{F} + \delta_0 F \Delta d_1]$$

Where $1_{SSD} = 1$ when the patient lives in Seine-Saint Denis and similarly, $1_{VD} = 1$ when the patient lives in Val-d'Oise. To make the interpretation of coefficients easier, we note $\tilde{\alpha}_0 = 1 - \alpha_0$, $\Delta d_0 = -\Delta \mathrm{d}_1$ and $\tilde{F} = -F$. This way all coefficients can be directly compared between the two districts except for α_1 and $\tilde{\alpha}_0$. Indeed, these two coefficients incorporate two effects : a general predominance effect of one district over the other (α_{SSD}) and the effect of living in the same district as the hospital (α_D). Namely we can write : $\alpha_1 = \alpha_{SSD} + \alpha_D$ and $\tilde{\alpha}_0 = \alpha_{SSD} - \alpha_D$.

This model is very general, but it is actually too flexible in the sense that it allows too many coefficients to be different which can lead to a lack of statistical power or in the same sense to overfitting. Indeed, we evaluate this model and conclude that all the considered effects are not statistically different between the two districts. For instance, the Fragility effect is not statistically different in the Seine-Saint-Denis district and in the Val-d'Oise one.

We thus turn to a simpler model in which we force related coefficients to be equal in each district allowing us to estimate more precisely average effects for the district of residence, fragility, distance and their interaction.

The model becomes:

$$P(y_i = 1|\Delta d_1, F, D) = \alpha_{SSD} + \alpha_D(1_{SSD} - 1_{VD}) + \beta \Delta d_1 + \gamma F(1_{SSD} - 1_{VD}) + \delta F \Delta d_1 (1_{SSD} - 1_{VD})$$

In practice, we construct the « oriented dummy variable » $(1_{SSD} - 1_{VD})$ which is equal to 1 when the patient lives in Seine-Saint-Denis and -1 when she lives in Val-d'Oise. This variable is crucial for the estimation because of the symmetrical situation for the choice between the two hospitals. It appears directly as a regressor and it is also interacted with the fragility index. It is not needed for the difference in distances which is already an « oriented » variable when

expressed with respect to one hospital in particular. The interpretation of the coefficients concerned by the « oriented dummy variable » is the following : a positive impact corresponds to an increase in the probability to go to the Saint-Denis hospital for the patients living in Seine-Saint-Denis while also corresponding to an increase in the probability to go to the Gonesse hospital for the patients living in Val-d'Oise.

Since the fragility index is only available at the IRIS level, we perform a grouped data estimation with each observation corresponding to an IRIS in which we measure the proportion of patients going to each hospital. Under the assumption that the error term is independent of the averaged covariates at the IRIS level (which seems sensible), the grouped data estimation leads to unbiased results like the estimation on individual data.

The following effects are estimated :

- α_{SSD} is the overall predominance of the Saint-Denis Hospital
- α_D is the predominance effect for the Hospital from the district of residence
- β measures the preference for the closest hospital ; because of the definition chosen for Δd_1, the coefficient is expected to be negative because when the patient is closer to Saint-Denis hospital, $\Delta d_1$is negative and the opposite when the patient is closer to Gonesse hospital
- γ measures the impact of Fragility on the probability to go to the hospital of the district of residence : a positive gamma means that more fragile patients are more likely to go to their district Hospital
- δ measures the cross effect between the difference of distances and the Fragility (in the district of residence) ; a positive coefficient mitigates the compound effect of distance and fragility, while a negative one reinforces it.

3. RESULTS

3.1 STATISTICAL RESULTS

The results of the estimated models are reported in Table 3. Each column corresponds to a variant of the model with different definitions of distances. The first model uses the time difference by car. It is the model that achieves the best fit on the data, and we shall concentrate on it for the comments. The other models (columns 2 to 4) show qualitatively similar results

which ensures the robustness of our approach showing that it does not depend on the definition of distance.

Table 3: Determinants of the hospital choice according 4 probabilistic models

	Differences in distances or time with second hospital			
	Time Driving	Dist Driving	Radial Distance	Transit Time
	(1)	(2)	(3)	(4)
Same admin district (Département)	0.288***	0.542***	0.425***	0.649***
	(0.032)	(0.031)	(0.029)	(0.035)
Δ Driving time (min)	−0.026***			
	(0.002)			
Δ Driving distance (km)		−0.016***		
		(0.002)		
Δ Radial distance (km)			−0.042***	
			(0.003)	
Δ Transit time (min)				−0.003***
				(0.0005)
Social fragility (div. by 100)	0.863***	0.486***	0.588***	0.314***
	(0.088)	(0.080)	(0.078)	(0.084)
Δ Driving time x Fragility/100	0.078***			
	(0.008)			
Δ Driving distance x Fragility/100		0.044***		
		(0.009)		
Δ Radial distance x Fragility/100			0.098***	
			(0.016)	
Δ Transit time x Fragility/100				0.002
				(0.002)
Intercept	0.377***	0.232***	0.280***	0.135***
	(0.016)	(0.015)	(0.014)	(0.018)
Observations	284	284	284	284
R^2	0.948	0.921	0.940	0.900
Adjusted R^2	0.948	0.920	0.939	0.899
Residual Std. Error (df = 279)	0.096	0.119	0.104	0.134

Note: *p<0.1; **p<0.05; ***p<0.01

Reading: Column (1) corresponds to the model in which proximity is computed with the difference in driving times between going to Saint-Denis and Gonnesse. Controlling for the other factors, the probability to go to one's district's hospital is 28.8 pp higher than going to the other hospital. One more minute of driving difference increases the probability to go to the closest hospital by 2.6 pp. One more point in social fragility index increases the probability to go to one's district's hospital by 0.86 pp. With one minute of driving difference, one more point of social fragility index increases the probability to go to the closest hospital by 0.078 pp.

If the sign of the variable is positive, then the factor is an increase in the probability to go to the Saint Denis hospital. If the sign is negative, this represents a decrease in the probability to go to Saint Denis. Therefore, positive values represent a rise in the probability of our model while

negative values a decrease. The value represents the relative weight of each variable in the model.

All coefficients show quite strong effects in magnitude and are highly statistically significant except for the cross-effect distance/fragility in the model using public transportation transit time as distance marker.

The intercept corresponds to a slight overall predominance of the Saint-Denis Hospital (52%). Although statistically significant this value remains quite small and confirms that both hospitals are equivalent in terms of attractivity as we mentioned earlier.

The district of residence effect is 0.144 and highly significant. It means that patients have 14.4 pp more chances to go to their district hospital even after controlling for other factors such as distance and fragility. In terms of magnitude, this effect is comparable to the one obtained with 5.5 minutes of driving time or 16.7 points of fragility.[4]

One more minute in the difference of driving time increases the probability to go to the closest hospital by 2.6 pp. Moving from the 25th to the 75th percentile of driving time difference inside a given district corresponds to an increase of about 10 minutes which in turn corresponds to an effect of 26 pp in favor of the closest hospital.

One more point of fragility as measured by our social fragility index increases the probability to stay inside the district of residence by 0.86 pp (for reasons of readability, the fragility index was divided by 100 in the estimation). The social fragility index theoretically ranges from -30 in the wealthiest areas to +30 in the most fragile ones. In our sample, moving from the 25th to the 75th percentile of the fragility index corresponds to an increase of 16 points (10.21 to 26.11) which in turns correspond to an effect of 13.8 pp in favor of the hospital of the district of residence.

The cross effect between distance and fragility slightly mitigates the département effect, and this mitigation effect is stronger when fragility or difference in distances are higher.

[4] The data in table 3 shows a value of ,288 which is the variation in probability in the difference of distance, therefore needs to be divided by 2 to assess the probability of one choice.

Carrying further analyses on the cross effect show that the distance effect is smaller for the more fragile patients who are relatively more likely to choose their district's hospital than the wealthier ones, when the difference of distances decreases, or said differently fragility matters more in the decision to go to the hospital when the difference of distances becomes smaller. It is to note that the cross effect is not significant for one of the 4 models which makes it a little less robust than our main findings on district effect and fragility.

3.2 THE PRIMARY ROLE OF BOUNDARIES: THE "DÉPARTEMENT" EFFECT

The first result in our analysis is that the fact to be in the same "département" (also referred to as the administrative district) is a major factor for predicting the choice of the hospital, even after taking into account the difference of distances with Saint Denis and Gonesse. In the case of living in the département of Seine-Saint-Denis (resp. Val-d'Oise), the probability to go to Saint Denis hospital (resp. Gonesse) will be increased by a factor of 14,4 pp. in the Time driving distance model. This means that when they are at a similar proximity, be it expressed in pure distance (radial), driving option (distance or time) or public transport transit, patients will most likely select the hospital from their administrative unit.

It is quite meaningful to make a computation of the statistical equilibrium between the département effect and the distance one: indeed, if we measure at what moment both effects cancel each other, we are in a position to quantify the magnitude of the administrative district in terms of proximity. For instance, in the case of Time driving distance, the increase in difference in time plays a diminishing influence on the probability to go to the district's hospital: for each additional minute of time difference, this probability decreases by 2,6 pp. This means that crossing the "département" border is equivalent to an immediate change of 5.5 minutes in the difference of driving time. In other words, up to 5 minutes difference, there is still a stronger probability that the users will select the same department hospital even if it costs them 5 minutes to go there.

3.3 THE WEIGHT OF SOCIAL FRAGILITY ON PROXIMITY

The second result of our model concerns the role of the social fragility that increases the probability to go to the hospital that is located within the same département. Indeed, moving from the 25th to the 75th percentile of the fragility index increases the probability to go the district's hospital by a similar magnitude as the département effect (13.8 pp vs. 14.4 pp in the driving time model). The département effect is thus stronger for the more fragile patients.

Going a little deeper we find that the Fragility effect is more important when distances to both hospitals are similar. Indeed, when patients are close to their district's hospital, they have a naturally high probability to choose it whatever their Fragility. However, when moving in the direction of the other hospital, an increasing fraction of patients tend to switch to the other hospital (although still a minority of them), and the ones who switch tend to be the wealthier ones. This result is verified when crossing the département border and also more gradually when the difference in distances changes (this last effect is however a little less robust than the border effect). This finding further enriches earlier researches on the role of age or deprivation on a patient ability to cross distance (Graham, 2018) by illustrating how the cognitive effect of deprivation generates spatial boundaries.

DISCUSSION

Our contributions researches are twofold : first we mobilize an innovative quantitative method to scrutinize spatial behaviors, and second we highlight the fact that spatial behaviors are not isomorphic but follow a pattern influenced by frontiers.

4.1 INNOVATIVE QUANTITATIVE APPROACH

The first contribution of our article is methodological. We developed an original model of measuring patterns of behaviors based on homogeneous population dwelling. We thus avoid spatial traps identified in the literature (Vallée, Le Roux, Chaix, Kestens, & Chauvin, 2014). Using the IRIS statistic zoning proves to be a powerful tool for understanding comparable units' behavior. Another methodological contribution is the use of a relative spatial unit defined as a relative distance measurement. Instead of measuring distance from habitant location to a care facility, we developed a measurement of the difference of distances between two points (linear, road network, time based and public transport). This modelling then supports a probability model evaluating the relevant variables that eventually play a role in the selection process between the two care facilities.

In terms of methodology subjective proximity is usually reported in qualitative type of survey, through mind mapping or open questions such as "to whom or what do you feel closer?". In our research we have used an innovative quantitative approach, that has revealed cognitive effects over a large sample of population on the variation in their behavior patterns when situated in a similar proximity. The use of a model of multi variate analyses of variation of behavior patterns that includes deprivation indexes is of great importance for health decision

and resources allocations (Spielman & Yoo, 2009). Indeed, our research shows that people behave spatially according to the context in which they are embedded, a process with a reinforcing capability: if the context expresses that the location is too far, the mutual and recursive actions will ultimately demonstrate it is indeed "too far".

4.2 VARIOUS COMPONENTS OF SUBJECTIVE PROXIMITY: A FRONTIER EFFECT

Following the previous results, our main theoretical finding is to give weight to some of the various components of subjective proximity. Among these social, institutional and economic dimensions we evidenced what we call a *frontier effect*. This frontier effect in our case is by nature cognitive. This result is relatively counter intuitive as it drives people to select a hospital that may prove to be the farther up to a certain limit.

This finding complements earlier researches on how individuals structure judgment about proximity : using generic spatial models Charreire et al. (2010) mention that density as well as the degree of accessibility explain the potential of an area. Density gives an indication on the amount of available resources in an area, not necessarily providing an explanation of how these resources can be gained. Accessibility gives a deeper indication on the affordance of such resources, or their alleged closeness.

One of notion at stake here is the notion of "impact area" as developed by Brennan and Martin (2012). Basically, in an overlapping area, an object may have a greater influence than another and may be considered to be at a closer proximity even if it is further in Euclidean distance. This notion, theorized as the impact area of objects, is particularly relevant for situations where resources are close one to the other, or included in larger clusters, like administrative clusters (Grütter, 2019), which particularly corresponds to our case.

We thus illustrate how perceptual boundaries influence the way individuals hierarchize objects in space, creating various level of importance among them and leading to potentially misjudge the distance between them.

4.3 INFLUENCE OF THE LEVEL OF DEPRIVATION ON THE SUBJECTIVE PROXIMITY

The second effect we evidence is the influence of the *level of deprivation* on the subjective proximity. Indeed, the cognitive construction of proximity is affected by social fragility, leading to a poverty trap since people with high deprivation index have more probabilities to select a

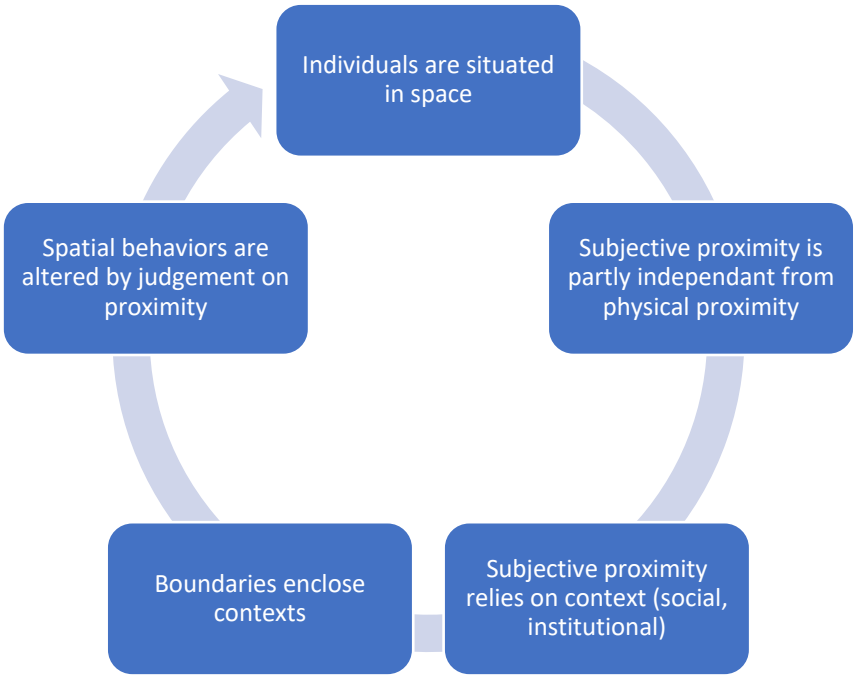
hospital that requires more time and resources to reach. The cognitive barrier increases poverty trap in spatial behavior.

This finding resonates with similar results on the subjective proximity in particular the fact that subjective proximity is not necessarily associated with physical proximity. In some instances, on the contrary this judgement on proximity is stronger with individuals that are located farther revealing a paradox of distance (Wilson, O'Leary, Metiu, & Jett, 2008). In the abovementioned study, the authors demonstrate that the sense of proximity is structured by social processes. Our results show the adding effect of deprivation on the spatial lock-in process. Indeed, deprived population show a higher probability to choose the farthest hospital thus spending more resources to reach it.

One of the theoretical implications from our research is to reassess the role of context in the shaping of proximity and eventually in the properties of objects: the context here is defined by administrative frontiers (or boundaries) and by social conditions of the actors (also dependent from such boundaries). Our statistical results show the combined magnitude of contextual situation on collective behaviors, demonstrating a significant statistical effect. As described by Dale and Burell (2008), the situatedness of spatial dimensions creates the condition for recursive actions that in return shape the way space is apprehended, understood and lived. We have here a case showing how this process works and reinforces mutually. It is not a surprise, since the "département 93" in which Saint Denis Hospital is located is one of the poorest in population in France, according to national statistics. District boundaries enclose a social reality that creates its own judgement on proximity. Within these boundaries, drawn not only by an administrative invisible line, but by social context, inhabitants assess differently than pure Euclidean metrics what is close or near.

The theoretical proposition we suggest is summarized in figure 3 here below.

Figure 3: theoretical proposition



4.4 PRACTICE IMPLICATIONS

Our contributions have managerial implications, particularly in the process of establishing proximity-based decisions, such as in the case of organizing health around proximity territories, as currently developed in rationalization of medical resources.

As demonstrated in the statistics above, the behavior of patients seems therefore not to be driven by pure rational analysis of a Euclidean distance or a time to travel efficiency. Their judgement about proximity as revealed by their behavior is not isomorphic: indeed, in a situation of equivalent physical proximity, all things being equal, patients should visit at equal terms both hospitals and not select one hospital above the other. Our results tend to indicate a relationship between deprivation and sense of proximity. Deprived population tend to select the hospital in their department even if it is not the closest. Social deprivation influences proximity perception, widening the gap between the physical proximity (be it physical or temporal) and its perception.

The main managerial contributions concern spatial asset location, investment or resources allocation since our research recommends including cognitive proximity effects in the analysis: how do people will apprehend a sense of nearness with that object? How contexts and boundaries may modify the judgement on closeness to an object? Understanding the effects of subjective proximity is therefore an important step when making decisions of allocation of

medical resources. Distance in Euclidean terms cannot be the only marker; judgement on distance may clearly drive to solutions that are contrary to a sole measurement of physical distance.

This case contributes strongly to the managerial and organizational discussions in the health sector. Organizing health services is a current hot topic, following the public policies of alignment of resources in basins of population. Understanding the impact of perception of proximity reveals how cognitive factors can play a disturbing role in decisions driven by objective measures of distance. The organization of a GHT that seeks to implement and rationalize service offer may fall apart, in particular for the deprived population for whom intangible frontiers mark the landscape. More generally these learnings could be extended to public services management as a whole.

CONCLUSION AND LIMITATIONS

The purpose of this paper is to apprehend the question of nearness as experienced by users in the medical system and thus capture their sense of subjective proximity. We use a statistical approach, analyzing the behavior patterns of around 725 000 inhabitants in a suburban area north of Paris in a situation of equivalent distance between two hospitals: what hospital do they select, and what variables may explain the variance if any? Indeed, all things being equal, under a rational distance or physical proximity model, there should be no difference in the frequentation of one or the other hospital located at same distance. Our results show that on the contrary two main variables modify the “all things being equal” paradigm: a frontier effect, whereby the probability of visiting one hospital increases if it is located in the same administrative district; a social effect, where the level of deprivation, calculated on an index gathering 11 social fragility markers, influences the subjective proximity of the inhabitants: the more deprived they are, the less they choose the hospital based on objective proximity.

These conclusions are of importance: they offer an interesting methodological approach on the measure of proximity, using difference of distance metrics and computing individual behaviors through the analysis of statistical units developed by the INSEE in France, named IRIS. These results offer new perspectives to understand the role of subjective proximity in organizational life. The first theoretical contribution is that subjective proximity is context dependent, such context being drawn by boundaries (social, institutional among others). This contributes to the researches on places, boundaries and institutional work or social movements. The second

theoretical contribution relates to the role that subjective proximity has on objects: it does change the properties of that object above its objective nature. This contributes to researches on impact areas in particular.

Of course, this research has some limitations, in particular due to the specific nature of health activities deeply related to emotional aspects. The research could be replicated in other areas, such as marketing or merchandising for instance to check the confirmation of results. The second limitation relates to the fact that we could not capture the role of "prescription" in the construction of the judgement on proximity: indeed, some third parties, mainly doctors, certainly have a leading role in constructing subjectivity patterns of proximity among the patients, influencing the choice of the "right" hospital. We could not measure this variable through our quantitative study. A more in-depth qualitative review could evaluate the role of third parties in shaping the context, drawing boundaries and defining what the "right" judgement about proximity is.

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