Revealing the role of subjective geographic proximity in the use of medical services: a quantitative case study in a French metropolitan suburb

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Abstract:

Planning or organizing health services across territories relies mainly on density models and metric management which do not match the complexity of spatial behaviors of individuals. Thus, unexpected behaviors may be observed, leading to misalignment with the initial plan. Our paper addresses this issue by analyzing the influence of some socio-economic factors on the venues of inhabitants to hospital facilities within a Groupement Hospitalier de Territoire, by essence an organisation of medical resources within a defined territory. By comparing the patterns in a situation of comparable choice between two hospital facilities located at a nearby distance within the same GHT, we measure some counter intuitive variances, revealing a perception of proximity that diverges from pure distance and is statistically correlated to two main variables: the level of deprivation and a perceived boundary that matches the frontier of the administrative department. We thus evidence some factors supporting cognitive dimension of proximity that ought to be integrated in the future programming of patient's parcourse.

Keywords: Space, Health, Proximity, Context, Subjectivity

INTRODUCTION

Decisions of medical resources location face spatial dilemmas (Lowe and Sen, 1996). How to ensure consistent and equal access to medical facilities by the majority of habitants within an area? In 2016, France passed a Law of modernization of the health system which specifically included a chapter dedicated to the improvement of the territorialization of health services by organizing the decentralization of administrative authorities in regional cluster (entitled ARS or "*Agence Régionale de Santé*"). Each ARS supervises health service offer within their area in due negotiation with local political instances (Truchet, 2017; Duchesne, 2018), redesigning allocation of public medical facilities, including large university hospitals, to match with population settings and health expectations. This process has been conveyed together with the creation of GHT or "*Groupement Hospitalier de Territoires*" consisting of administrative groupings of two or more large hospital, sharing their activities within a spatial area (Bertrand, Michot, & Richard, 2018). The purpose of the 2016 Law is thus to improve the access to health, for defined territories, by ensuring an adequation between the geographical spread of the population and the offer of medical services (IRDES Reports of 2016, 2018). In such circumstances, decisions to close or merge hospital activities have been conveyed by the actors in charge of implementing GHT territories. A main reference in the delimitation of GHT territories has been the department, which is a convenient scale due to its institutional dimension allowing proper proximity-based decisions.

However, the search of such proximity, a concept that is always positively connoted, as evidenced by the expressions such as "proximity management," "proximity police" or "proximity justice," is far from being homogeneous across the various GHT and probably marks one of the stringent issues in the deployment of the GHT. As the French Court of Auditors (Cour des Comptes) summarizes in a 2020 report: *"the territorial organisation of GHT could have generated an opportunity for authorities to improve the situation in terms of equality of access to health services across the country. It is now obvious that the effects of GHT in this perspective are not at the expected level. Without a further change in their geographic perimeter, a large portion of the GHT will not meet this objective".* The efficiency of the results of the GHT can be made through the lens of Euclidean distance or time travel distance which reveals huge discrepancies in terms of travel distance between the various GHT, evidencing difficulties in meeting the objective of improvement of access.

Because of the above, expressions of discontent have emerged in few areas, as in the case of maternity services, where both the population and the medical teams have argued that in such

instance, the need for psychological comfort, or the feel of proximity is a predominant factor to take into consideration above pure distance metrics. Distance is not considered equal whether patients live in a rural area or in a densely populated area, because of heterogeneity in the dispersion of health facilities across the country, especially large hospitals which form the backbone of the GHT (Conti et al. 2020). Furthermore, access remains contingent to social variables, among which the level of poverty plays a crucial role: the more deprived are the population, the more complex it is to access a health facility. Considering the various understandings of proximity for individuals, it is important for public decisions on medical resource allocation to fully understand what constitutes proximity in the access to health, not only in terms of distance, but also in terms of deprivation or precarity. Focusing on this blind spot in the organisation of health policies may avoid unexpected outcomes such as over frequentation in dense areas or lack of medical support in more remote areas.

The purpose of our paper is precisely to answer this long-debated question: how do individuals concretely select a hospital structure within a GHT; do they only refer to Euclidean distance? Using an econometric regression model, we develop a comprehensive statistical analysis that reveals the role of two variables at play in the notion of proximity. Our case study focuses on the spatial behavior patterns of the population within the GHT of a deprived urban area, representing approximately 725 000 inhabitants. When situated at similar distance, we observe differences in perception of proximity depending on level of poverty, as well as the existence of an administrative frontier, introducing a subjective dimension in the appreciation of proximity.

Our paper is divided in four sections. In the first part, we will review the underlying notion of proximity and access in the creation of the GHT over the past 5 years in France. In the second part we will review the theory about geographic proximity. The third part will be dedicated to the case study and the methodological approach. The fourth part will report the summarized results. In the final part we will discuss our results.

1. CONCEPTUEL FRAMEWORK

1.1. GHT AND TERRITORIAL ORGANISATION

The purpose of the GHT territorial organisation is to “ensure an equality in the access to health services”, through an adequate definition of territories around existing health facilities and in line with existing decentralized authorities (Dagorn et al., 2021; « Focus », 2016). However

this notion of territory remains vague in the Law and has to be appreciated on a case by case basis by the stakeholders involved in the foundation of a GHT (Cazin, 2017). As an illustration, the Court of Auditors evidenced that 43% of GHT are covering a perimeter within a French department, one third are embedded within the French department and a remaining 23% of GHT are crossing French department, or in a few cases regions (Cour des comptes, 2020).

This variance in territorial size is correlated with a heterogeneity regarding access time to the main hospitals that constitute the GHT. If median access times to hospitals have remained quite homogeneous across time, increasing from 16 minutes in 1980 to 17 minutes in 2013 (Conti et al., 2020), the Court of Auditors report of 2020 shows that an important dispersion of travel times may be observed, essentially linked to the size of the GHT : *« Although a GHT does not encompass a determined geographic area, it is feasible to establish based on the notion of recruitment zone an approximated area for a GHT, comparable to a natural area of attraction. As such, in average GHT represent an area of 4 154 km2, or 73 % of the surface of a French department. However this value hides huge discrepancies: for instance, the smallest GHT (GHT 94 Nord of 81 km2) represents less than 0,5% of the surface of the largest GHT (GHT Limousin, weighting 16 942 km2). Distance in travel time therefore vary significantly across the various GHT »*

Therefore, when the definition of a territory is delegated to the stakeholders in charge of defining its boundaries the result is that the access conditions to the various hospitals included in the GHT are extremely variable, be it in pure distance or in travel time. The geographic distance that separates patients to their main hospital therefore remains open and an unresolved issue at a global scale.

The heterogeneity of GHT does not only deals with distance or geography, it also covers discrepancies in social issues. First, GHT in urban territories vary from GHT in rural areas as the dispersion of hospital facilities varies greatly according to the level of urbanization and population density (Conti et al., 2020). Secondly, at comparable levels of population density, social and income disparities vary across the GHT territories.

As an illustration, across the various GHT in the metropolitan area around Paris (Île de France), we observe great variability in precarity or deprivation levels. Based on a map evidencing score of fragility per IRIS units that we computed (Chesnel et al., 2017), evidence shows that there is an important variance in the scores of distinct IRIS. Furthermore, this dispersion reveals a concentration of deprivation in northeast IRIS of the metropolitan area, basically covering the

French department of Seine Saint Denis and Val d'Oise (IRIS colored in purple red in the map 1, cf. p. 10).

Moreover, it has been observed that "the patients in the natural zone of the Saint Denis hospital (one of the two hospitals of the GHT) are five times more fragile on our index that the average population in Île de France, and twice as more as the average of the French department Seine Saint Denis as a whole" (Chesnel et al., 2017). And, according to the latter authors, the variances may be observed within the French department range : "48% of the population that lives within the accessibility range of the Saint Denis CH comes from IRIS that are extremely fragile (index 4 on our scale), to be compared to 22% only in the natural accessibility area of other hospitals in Seine Saint Denis".

Consequently, if a significant variance is observed within the fragility of the population that lives in close proximity to the hospital, it is worthwhile to investigate whether this fragility plays a role in access to the health facility. Indeed, the literature has outlined the relationship between the level of deprivation and access to health. For instance, it has been demonstrated that accessibility is rendered more complex for inhabitants of deprived areas (Hawthorne & Kwan, 2012, 2013). The fact to live in a socially stigmatized area prevents the populations to pull out of this area, creating a social trap, for which the patient doctor relationship may not prove sufficient to overcome.

If distance remains the initial entry point to encompass the equality in access to health, it appears to be a factor that may be mediated by the deprivation level variable, in the sense that social fragility creates spatial traps. This assessment is in line with the theoretical foundations of the school of proximity which states that proximity is not only of geographic essence but also includes other dimensions.

1.2. GEOGRAPHIC 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 organisation, "rightness" being evaluated under the lens of costs and externalities towards spatial measurement (Fujita & Krugman, 1995; Krugman, 2000).

As an alternative answer to economic geography, proximity has been developed as a notion mobilizing non-geographic terms. Proximity addresses (i) to which extent there is "nearness" between organisations or actors, and (ii) what outcome the different dimensions of proximity

may bring to interaction (Torre & Talbot, 2018). 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). Scholars of the school of proximity have identified several dimensions of proximity, each of those having a distinct influence on the level and nature of interaction. For example, the five iconic dimensions are geographic, organized, cognitive, social and institutional (Boschma, 2005) and each of them provides an effective operationalization and measurement. This article focuses only on geographical proximity within a GHT.

Indeed, 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 (Rainham, McDowell, Krewski, & Sawada, 2010). The location of actors into space is therefore questioned: geographic proximity is to be defined as the distance that separates actors, organisations or objects, however a distance that is mediated by the monetary and temporal cost to overcome it (Torre & Rallet, 2005). Distance then becomes an obstacle to cross, and the ability to cross it depends on multiple resources from monetary to organisational.

There are multiple ways to apprehend this distance from a cognitive perspective: the initial and first thought goes to the linear distance in meter or kilometer that separate two entities in a straight line (bird fly) (Rychen & Zimmermann, 2008). Of course in our urban areas actors use transport infrastructure like roads or trains to cross that distance: therefore the geographic proximity can be measured using a road map (driving distance in kilometer), or a GPS type of map that measures time to reach destination (based on a GIS application, taking into consideration density of traffic) (Gilly & Torre, 2000). The same computation can be made using railways or metropolitan tube as the reference (transit time, measured in minutes). However, it is important to outline that whatever the model of measurement, it implies a minimum sacrifice of resources (monetary, time) that will be felt differently between the individuals, depending on their wealth or social condition (Torre, 2018).

Depending on the modality or frequency of the transport mode chosen, this sacrifice may be considered as prohibitive for some segments of population. To measure the influence of this cost of distance, we decided to use a proxy that measure the social fragility of individuals (Chesnel et al., 2017), in order to confirm the influence of deprivation levels on the accessibility to the health facility. Our assumption, based on the proximity literature is that it is more difficult for deprived persons to overcome distance due to the monetary or resource-based constraints;

furthermore, the analyses carried on the social stigma of deprived areas should reinforce the monetary effect adding a representation layer to the difficult to overcome distance.

Hence, we will select the following variables to measure 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
	Social ties	District

Our paper aims at analyzing access to a hospital in a deprived urban population, through the notion of proximity (geographic) and the social variance. 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).

As discussed earlier, common sense, in particular within the principle of equal access to care on the national territory, may assume that the choice to go to one hospital only depends on distance. We will observe the role of social variables and their impact the choice of frequentation of one or the other hospital, even when we have neutralized the effect of distance.

2. METHOD

2.1 CASE DESCRIPTION

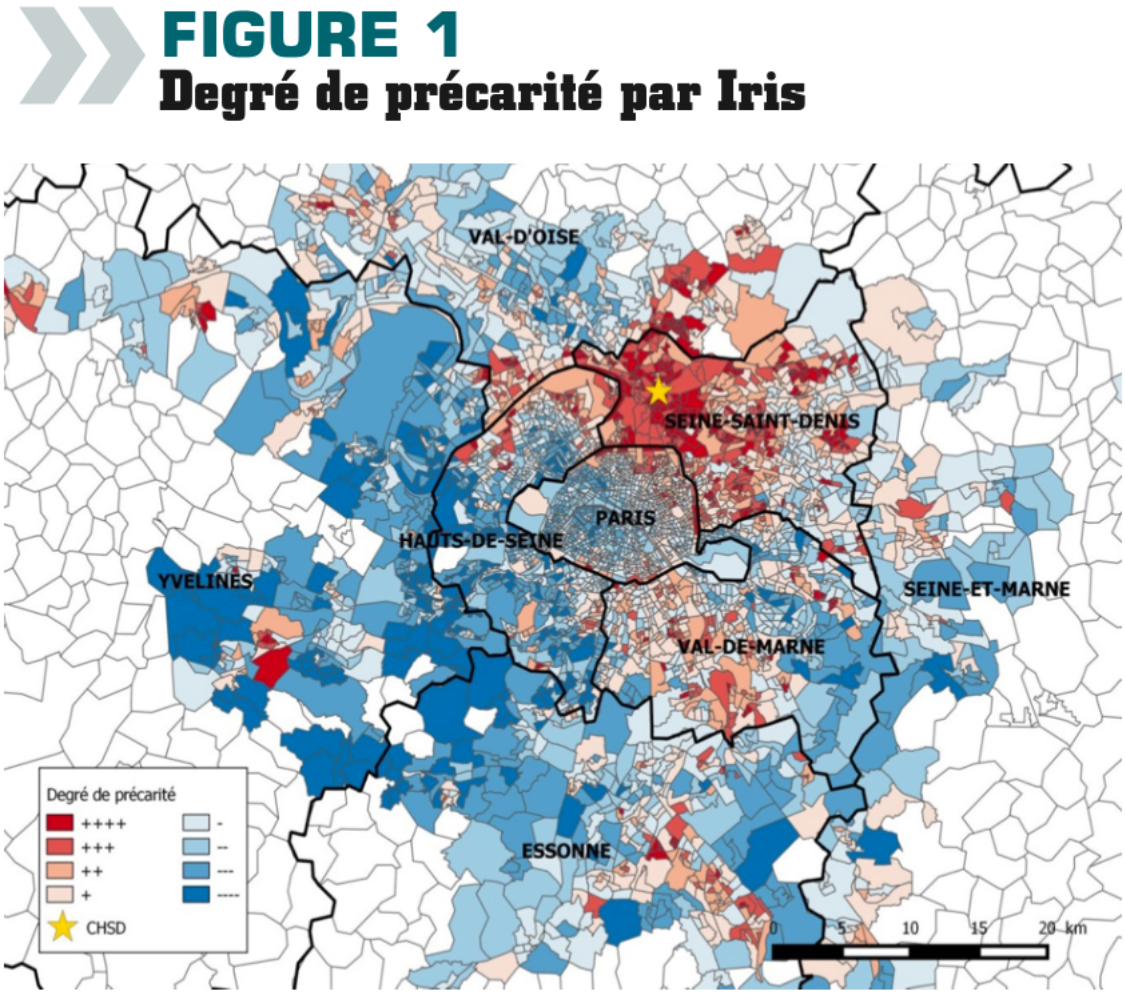
The case study covers the organisation of a GHT in the northern part of the Great Paris Metropolitan area (GMP). The map illustrated in figure 2 pictures the Paris Metropolitan area and the location of the two hospitals that form the GMP entitled "Plaine de France" CH Gonesse and CH Saint Denis, which we will later refer to as Gonesse and Saint Denis.

The choice of this GHT as a unique cas (Yin, 1999) has been made on multiple factors. We chose to work on one of the 15 GHT created in Île de France, excluding Psychiatric GHT. In order to measure the effect of distance and precarity on venues, we searched for a case where distance would not exceed a certain level of dispersion as well as where the level of precarity would be high. In the GHT Plaine de France, the minimum and maximum values in travel time range between 14 to 18 minutes – with a low dispersion between the two values (in comparison the GHT Île de France Sud has a dispersion of 11 to 53 minutes in driving time) (source : solidarités-santé.gouv.fr).

We computed a map of precarity in Île de France, using our fragility index for each of the IRIS composing the area. The result is shown in the map 1. Colors indicate the level of fragility, and we easily observe that the red (high precarity) is concentrated in the northeast quadrant where the GHT Plaine de France is located. Finally, and it is linked to one of our main findings, the GHT is one of the few in France that overlaps two departments, hence has an administrative frontier in its territory.

Figure 1: map of the Paris Metropolitan area and level of precarity per IRIS.

Source: Veltys



Furthermore, GHT Plaine de France could be compared to a "merger of the equals". Both hospitals provide general "proximity" services and are equivalent in size and service offer.

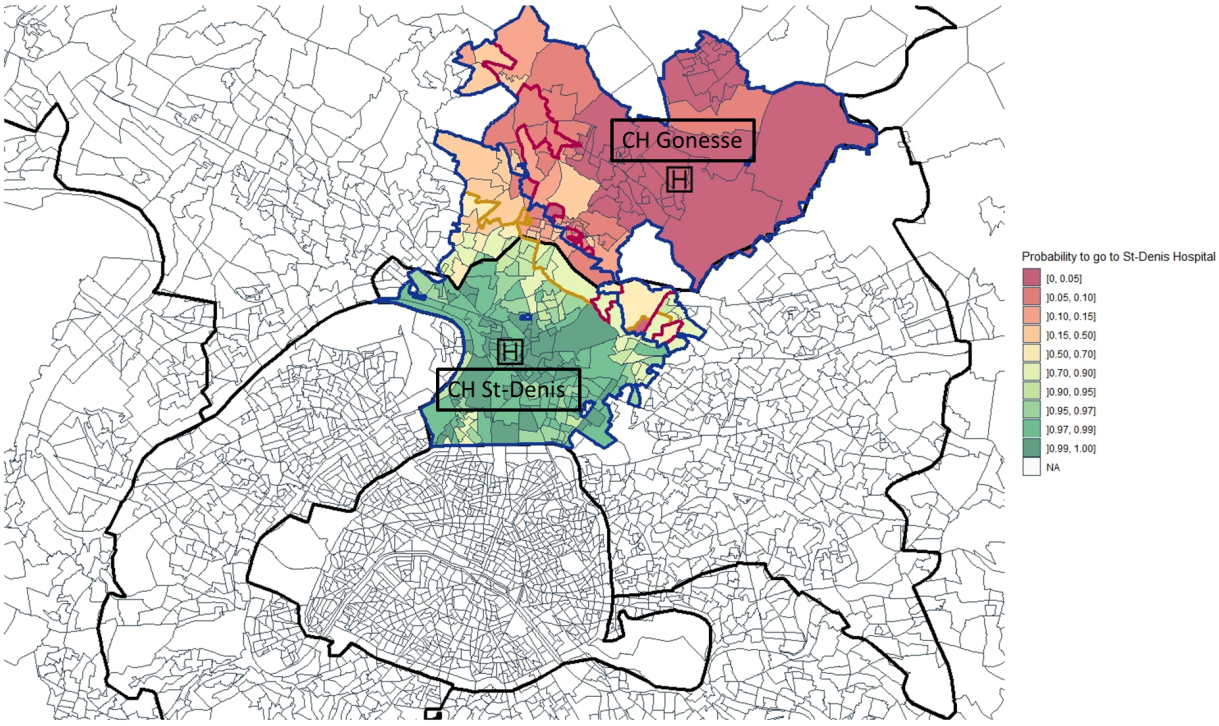
Multiple sources confirm there is an equivalence in service offer between the two hospitals: first they are not specialized in psychiatry or cancer treatment (CLCC); second, the documentation forming the mutual agreement at the GHT foundation highlights the equivalence in size and service offer. Third, the case mix deep analysis shows a very strong similarity in offer and volumes, as well as the number of practitioners in both hospitals

What is important is to ensure that none of the hospitals are polarized toward specific pathologies for each of the districts thus avoiding frequentation variations that would result from differences in service between the two hospitals and discrepancies in the pathologies of the populations between the two departments. 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) B) Once the difference in distance is considered, there is no reason for patients to select the hospital in their district, unless such a choice reflects a distortion in the perceived proximity.

Figure 2: 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.

For confidentiality reasons, data at the individual level was not available and we only had access, for each IRIS, to the share of patients who visited each hospital. This proportion comes from exhaustive administrative data and is therefore exact. However, no other information is known regarding the patients besides their address. This is the main reason why the analysis concentrates on location-related information (distance and fragility of the neighborhood). Our sample concentrates on the area around Gonesse's hospital and Saint Denis's hospital which

covers 284 IRIS representing about 725000 persons, corresponding to one fourth of the total population of Seine-Saint-Denis and Val-d'Oise districts and in line with the estimated value of population covered by the GHT in solidarités-santé.gouv documentation. In subsequent analysis the number of observations reported is the number of IRIS (284), but the number of underlying venues is much larger (estimated to be in the order of 50 000).

On a national basis the sample we choose with this GHT falls within the range between 988000 inhabitants in average per GHT when a CHU is the central facility to 378000 inhabitants for GHT without a CHU. 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 research.

Information about the individual's frequentation of a hospital is computed 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.

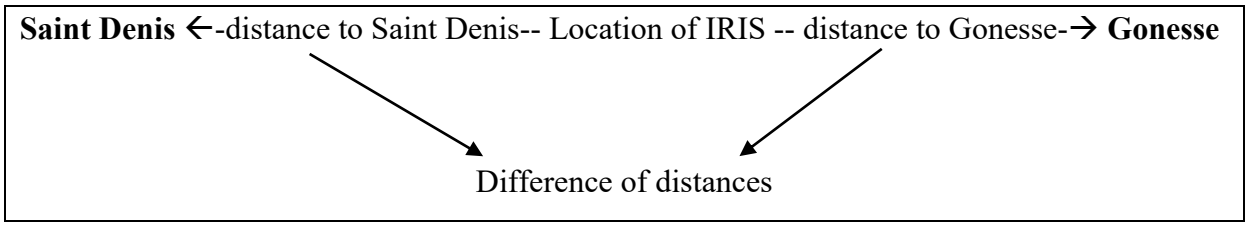
Administrative data at the IRIS level come from open data and have been used to compute the social fragility index. This index is built around eleven variables: median revenue, share of social allowance beneficiaries (RSA, dwelling, CMUC, single parents, share of beneficiaries covered at more than 50%),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

long term, unqualified) (Chesnel et al., 2017). Finally, distances were computed using various APIs, and in particular the one from google maps. An API is an application programming interface providing geo coding data.

2.3 STATISTIC MODEL

The data we compute for assessing proximity 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 3 and calculate the difference between the two values under the formula: Distance to Saint Denis minus Distance to Gonesse.

Figure 3: 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:

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

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.

2.4. DISCUSSION OF HYPOTHESES

The main question regarding the interpretation of the model is whether there could be some remaining omitted variables that would lead to a misinterpretation of the results.

Indeed, the estimated model is very parsimonious with only five variables but as will be seen in the next section, it achieves a very high fit, with an R^2 between 90% and 95%. This means that unobserved heterogeneity accounts for a very small part of the overall variance.

Both hospitals are very similar as stated previously, but could it be a problem if they were really different? For instance, if one hospital had a better reputation than the other one, such effect would be captured by the constant term, but it would not change the impact of distance and fragility in the overall model.

In our view, the only potential problem would be if each hospital had specialized in diseases that would be specific to the inhabitants of each district. However, and as highlighted previously this is not the case because both hospitals are quite large and cover the whole range of medical specialties as we checked on their website and www.scansante.fr where their case-mix can be compared.

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 to probabilistic models

Table 4: Determinants of Hospital choice

	Differences in distances or time with second hospital			
	Time Driving	Dist Driving	Radial Distance	Transit Time
	(1)	(2)	(3)	(4)
Same admin district (Département)	0.144***	0.271***	0.212***	0.324***
	(0.040)	(0.029)	(0.033)	(0.023)
Δ Driving time (min)	−0.026***			
	(0.003)			
Δ Driving distance (km)		−0.016***		
		(0.003)		
Δ Radial distance (km)			−0.042***	
			(0.006)	
Δ Transit time (min)				−0.003***
				(0.0005)
Social fragility (div. by 100)	0.863***	0.486***	0.588***	0.314***
	(0.188)	(0.124)	(0.146)	(0.086)
Δ Driving time x Fragility/100	0.078***			
	(0.016)			
Δ Driving distance x Fragility/100		0.044***		
		(0.014)		
Δ Radial distance x Fragility/100			0.098***	
			(0.029)	
Δ Transit time x Fragility/100				0.002
				(0.003)
Intercept	0.520***	0.503***	0.492***	0.459***
	(0.006)	(0.008)	(0.009)	(0.015)
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[1].

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.

In addition, the cross effect between distance and fragility slightly mitigates the French department effect, and this mitigation effect is stronger when fragility or difference in distances are higher.

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. Said differently, fragility matters more in the decision to go to the hospital when the difference of distances becomes smaller. It

[1] 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.

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 INVISIBLE BOUNDARIES

The first result in our analysis is that the fact to be in the same "*département*" (referred to as the French department in this paper) is a major factor for predicting the choice of the hospital, even after considering the difference of distances with Saint Denis and Gonesse. In the case of living in the French department 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 French department effect and the distance one: indeed, if we measure at what moment both effects cancel each other, we are able to quantify the magnitude of the French department 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 French department 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 French 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 French department. 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 French department effect (13.8 pp vs. 14.4 pp in the driving time model). The French department 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 French department 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 research 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.

4. DISCUSSION

Our contributions highlight the fact that spatial behaviors follow a pattern influenced by frontiers and deprivation level, which drives to theoretical as well as managerial implications.

4.1 THE COGNITIVE EFFECT OF AN INVISIBLE BOUNDARY

Among the social, institutional, and economic dimensions that create a disruption in the assessment of geographic proximity 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 research on proximity adding cognitive barriers in the assessment of accessibility (Charreire et al., 2010), adding. And for Brennan and Martin (2012) where resources are close one to another, administrative clusters may play a greater role in assessing proximity than Euclidean distance (Grütter, 2019). Our research confirms the influence of perceptual boundaries on the hierarchy of objects in space by revealing their statistical importance on the behavior of a large sample of population.

It reveals another dimension of geographic proximity which is more of a cognitive essence (Wilson et al., 2008; Cariou, Ferru, & Rallet, 2018; authors, 2020). Cariou, Ferru et Rallet (2018: 1124) highlight that " the analysis of proximities was very early confronted with their subjective dimension. Therefore, geographic proximity cannot be reduced to a mere distance. The perception of this distance is crucial." The geographic proximity is based on a small spatial

distance, which provides ground for objectivity assessment. However, proximity is not reduced to this small distance. It integrates altogether a judgement, an interpretation on that distance, taking a more subjective turn. The idea of proximity consists therefore to qualitatively characterize a distance that was initially of quantitative measurement. It then becomes subjective and contingent to the inherent logic of each Subject: “it is the Subject, and him alone, that holds the key to his proximity for a defined situation” (Le Boulch, 2001, p. 4). The geographic proximity finally ends to be characterized by the perception of individuals on the very nature of that distance that separates them. This perception is dependent from the capacity of each of the self to measure distances, map an itinerary or consider its capacity to overcome obstacles such as boundaries.

How would a frontier effect modify the perception that individuals have on the proximity to an hospital? One must refer to non-geographic dimensions of proximity described by the literature to understand this result: the fact that individuals belong to the same French department creates a feeling of belonging to a place which supersedes the Euclidean plan dimension. Indeed, place belonging carries identity construction, shared representations and meanings for individuals referring to this place; in this perspective the notion of institutional proximity highlights how individuals share both formal and informal institution that locates them in a common set of rules, scripts, values and routines. Individuals would then consider they are closer to a hospital that is located in the same place in which they live, to the detriment of distance be it in metric or time measurement, because of the prevalence of place belonging in the perception or self-assessment of their proximity (Lussault, 2007).

4.2 INFLUENCE OF THE LEVEL OF DEPRIVATION

Our results also illustrate that the ability to overcome boundaries is depending on the level of fragility as measured by our index. The more deprived, the less material or cognitive resources to overcome obstacles, even if not material but symbolic, like an administrative frontier. This result thus complements literature on social stigma and access to health facilities.

On a theoretical approach, our finding resonates with previous works on subjective proximity. In health issues, the level of medical condition or level of criticality has been considered to alter the judgement on geographic proximity (Johns, Foster, et Upadhyay, 2017). In the abovementioned study, Wilson, O’Leary, Metiu, and Jett (2008) demonstrate how social processes structure the sense of proximity. Furthermore, our results reveal that deprivation

adds 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. It gives a primary importance to the contextual socio-economic factors that builds the judgement on distance.

4.3 MANAGERIAL IMPLICATIONS

Our contributions have managerial implications, particularly in the process of establishing proximity-based decisions, as in the case of organizing health within defined territories, as currently developed in the GHT organisation.

Firstly, as demonstrated in the statistics above, the behavior of patients seems not to be driven by pure rational analysis of a Euclidean distance or a time to travel efficiency. Their judgement about proximity 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 the perception 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: 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. The organisation 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. In particular, the various information that are available from the Census, including social criteria, should be integrated into a multivariate model to mitigate the pure role of metric distance in health services organisation across a territory. However, as we mentioned proximity being a perception, the “threshold of proximity” does not exist in absolute value or terms because it depends from objective and subjective factors (Rallet et Torre, 2007).

This complexifies the feasibility of a consensus about the right location of a hospital within a territory. Still, establishing a dialogue or constructive discussion with the various stakeholders that are involved in a GHT, and in particular the “Comités territoriaux des Elus” who are in

direct relationship with the inhabitants of the GHT, would create an opportunity for building realistic scenarios on health parcourse applicable to the population living in this GHT.

Second, our research may pave the way for integrating these spatial data in the information systems of the GHT in order to structure patient's information around accessibility information. The data may derive from their address, using models that will generate assumptions on access modes and travel time with no additional input from the GHT administration. Such data could be linked to fragility index (either grouped through the IRIS global value, or individual depending on the fragility questionnaire) in order to highlight the more fragile patients that may require a closer and individual follow up in the health parcourse, to ensure that accessibility is guaranteed.

Third, geographic proximity is usually tied to trust, as it is considered to be the preliminary condition for ensuring a trust relationship (Nilsson et Mattes, 2015). This is particularly true in the patient doctor bond, as the singularity of the face-to-face contact, or close geographic proximity forms the basis of the trust between patients and doctors (authors, 2020). This reinforces the positive effect of geographic proximity on parcourse of health. Therefore, in situations such as COVID when the need to reduce physical proximity has revealed that other techniques such as e-health services –like e-consultation – have replaced traditional physical or geographical proximity with non-geographic proximities. This move confirms that any form of proximity remains crucial in the patient doctor bond, as it paves the way for a clearer communication, the building of a mutual trust, and the construction of common knowledge (cognitive proximity).

The use of technical interfaces improves the mutual learning between patients and health professionals, creating a common and shared meaning for the actions at play (Dumez et Minvielle, 2017; Dumez, Minvielle et Marraud, 2015). This is in line with recent works from Allaert and Quantin (2018) who reveal the need to study to various artefacts that build other forms of proximity with patient, whereby distance can be overcome by other forms of proximity.

CONCLUSION

The main contribution 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: an invisible frontier effect, whereby the probability of visiting one hospital increases if it is located in the same French department; a social effect, where the level of deprivation, calculated on an index gathering eleven 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 organisational life as previously pointed by Talbot, Charreire Petit and Pokrovsky (2020). 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 research on places, boundaries, and institutional work. 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 research on accessibility of an area in particular.

Moreover, evidencing the importance of social and cognitive factors in access to health highlights further the importance to incorporate those dimensions into the construction of tools and models associated with the parcourse of health. Individualized or granular data are key for the establishment of new forms of relationship and cooperation between health professionals and patients. In the absence of such understanding of the sense of proximity, empowerment of the patient may lead to unequal and dissymmetric access to health.

Of course, this research has some limitations, mainly relating to the fact that our analysis does not capture all factors that may modify the perception of distance. We could not capture the role of "prescription" in the construction of the judgement on proximity: indeed, some third

parties, such as doctors, certainly have a leading role in constructing subjectivity patterns of proximity among the patients, influencing the choice of the "right" hospital. In addition, the judgment that is made by a patient on the severity of his condition may modify its perception of distance. Criticality reduces the perception of distance: the more severe a patient estimates his condition, the more able he shall be to overcome obstacles.

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