

Semantic Cities - Studying the Mental Maps of Urban Centers

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*“Success has been and continues to be defined,
by getting up one more time,
than you’ve been knocked down”*

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Resumo

Encontrar o mapa mental de uma população tem suscitado um crescente interesse nas áreas de planeamento urbano e psicologia. No entanto, isto representa ainda um processo demorado e difícil, normalmente exigindo longas entrevistas presenciais e produzindo resultados impossíveis de quantificar. Para combater estas dificuldades, propomos o “Semantic Cities”, uma framework que engloba tanto o processo de criação e publicação de um inquérito acerca de mapas mentais, como o de análise dos seus resultados.

Para a implementar, começámos por descobrir as interações necessárias para que um inquérito digital sobre este tema produzisse dados tão fidedignos e eficazes quanto os produzidos por entrevistas presenciais. Depois, criámos uma forma simples de especificar um destes inquéritos, e de facilmente gerar a interface a partir dessa especificação. Por fim, concordámos em mais um standard, mas desta vez para descrever os dados produzidos por cada inquirido, fazendo uma ferramenta poderosa e flexível para analisá-los e exportar os resultados.

De forma a testar a sua eficácia, aplicámos a nossa framework a um caso de estudo acerca da cidade de Lisboa, e dos diferentes mapas mentais que lhe estão associados.

Palavras-chave: mapas mentais, framework, interfaces de inquéritos, psicologia espacial, percepção espacial, sistema de informação geográfico, manipulação de mapas

Abstract

Finding a population's mental map has seen increased interest in fields like psychology and urban planning. However, it represents a hard process to go through, often requiring long face-to-face interviews and producing results impossible to quantify. To address this difficulty, we introduce “Semantic Cities”, a complete framework to create and deploy a survey on mental maps, and to analyze its results.

To achieve this, we first uncovered the interactions necessary to make the data gathered by a digital survey, on this topic, as reliable and effective as the data from classic methods, such as personal interviews. Then, we created a simple way to specify such a survey. After that, we created an application that, from that specification, generates an interface to display the survey, and gathers the participations. Finally, we created a flexible and powerful tool to analyze the gathered data, and export the results.

In order to test its effectiveness, we put our framework to test by applying it to a case study about the city of Lisbon, trying to find the different mental maps associated with it.

Keywords: mental maps, framework, survey interface design, space psychology, space perception, geographic information system, map manipulation

Contents

Acknowledgments	v
Resumo	vii
Abstract	ix
List of Tables	xv
List of Figures	xvii
List of Listings	xxi
1 Introduction	1
1.1 Objectives	3
1.2 Contributions	4
1.3 Structure	4
2 Related Work	5
2.1 Environmental Psychology	5
2.1.1 How Immigrant Children Experience and Picture Their Neighborhoods	6
2.1.2 Mental Maps of San Francisco	7
2.1.3 Different Perceptions of a Place Brand	8
2.1.4 Psychological Maps of Paris	9
2.1.5 Investigating suburban environment by means of mental maps	11
2.2 Subjective Data Gathering	12
2.2.1 Boston's Crowdsourced Neighbourhood Boundaries	12
2.2.2 Mental maps applied to the coast environment	14
2.2.3 Psychological Maps of London	15
2.2.4 Drawing the City of Chicago	16
2.3 Data Driven Approaches	17
2.3.1 Twitter Languages in London	18
2.3.2 Where The Tourists Really Flock	18
2.3.3 Cities Pulse via Foursquare Check-ins	19
2.3.4 My Globe: Navigation Service with Cognitive Maps	20
2.3.5 The Livelihoods Project	21
2.3.6 Live Cities	23

2.4	Discussion	24
2.5	List of Requirements	26
3	Semantic Cities	29
3.1	The Host Server	32
3.2	The Database	33
3.3	Data Objects	34
3.3.1	Phases of type “survey-information”	35
3.3.2	Phases of type “questionnaire”	36
3.3.3	Phases of type “point-a-place” and “point-multiple-places”	37
3.3.4	Phases of type “draw-area”	39
3.3.5	Phases of type “draw-multiple-areas”	40
3.3.6	Creating a survey and the “survey creation tool”	42
3.4	Data Gathering Tool	42
3.4.1	“Survey Information” State	43
3.4.2	“Questionnaire” State	44
3.4.3	States with Map Interactions	47
3.4.4	“Point-a-place” and “point-multiple-places” states	47
3.4.5	“Draw-area” state	48
3.4.6	“Draw-multiple-areas” state	49
3.5	Data Analysis Tool	50
3.5.1	The Dashboard	51
3.5.2	The Analysis Screen	52
3.5.3	Analyzing data from “survey information” phases	54
3.5.4	Analyzing data from “questionnaire” phases	54
3.5.5	Analyzing data from “point-places” phases	56
3.5.6	Analyzing data from “drawings” phases	59
3.5.7	Filtering results	60
3.5.8	Results report and correlation analysis	62
4	Case Study: mental maps of the city of Lisbon	65
4.1	Survey design	65
4.2	Results	67
4.2.1	Participants’ background	68
4.2.2	Participants’ living area	69
4.2.3	Meaningful places and well-known areas	70
4.2.4	Official area of Lisbon	72
4.2.5	Neighborhoods’ mental maps	76
4.2.6	Case study conclusions	81

5	Evaluation	83
5.1	Evaluating the Data Gathering Tool	84
5.2	Evaluating the Data Analysis Tool	85
5.3	Discussion	85
6	Conclusions	87
6.1	Future Work	88
	Bibliography	89
A	Semantic Cities JSON Specification	91
A.1	Phases of type “questionnaire”	92
A.2	Phases of type “survey-information”	95
A.3	Phases of type “point-a-place” and “point-multiple-places”	96
A.4	Phases of type “draw-area”	98
A.5	Phases of type “draw-multiple-areas”	99

List of Tables

2.1 Summary of each project's approach, referenced by their respective section number.

"Manual" is used to describe face-to-face, human-executed, or just analogical processes.

"Part." stands for "partially", attributed to something that did not entirely fulfill the attribute. 25

List of Figures

2.1	Used techniques to understand children's subjective maps.	6
2.2	Map of the hills and roadways of San Francisco.	7
2.3	Resulting association network from interviews.	8
2.4	Resulting association network from online questionnaires.	9
2.5	Average distortion (dashed line) in the mental representation of the Seine.	10
2.6	Mental links to each stimulus.	11
2.7	Survey's results on the neighbourhood of Roxbury	13
2.8	The initial (left) and final (right) phases of the survey. For both maps, the darker the area, the more agreement in it.	13
2.9	The limits of the coast of Netherlands, according to 14 engineers.	15
2.10	Map of London with each region distorted by its recognizability.	15
2.11	Different drawings of the map of the city of Chicago.	17
2.12	<i>Tweets'</i> languages in London.	18
2.13	Resulting maps by locating the photos taken by tourists, in red, and locals, in blue.	19
2.14	Resulting maps by mapping check-ins sequences.	20
2.15	Different components of the MyGlobe service.	21
2.16	Resulting maps after the Livehoods clustering process.	22
2.17	Resulting maps after two different venue clustering modes.	24
3.1	Solution schema	31
3.2	Possible directory structure of a Semantic Cities host	32
3.3	The different database calls, and the processes behind them.	34
3.4	General structures for both data objects.	35
3.5	Specification of a "survey-information" phase.	36
3.6	General specification for "questionnaire" phases.	37
3.7	Specification of the different answer types.	38
3.8	Specification of the input produced by the different types of answers.	38
3.9	Specification of a "point-a-place" phase, and detail of a "mapView" object.	39
3.10	Input object generated by a "point-a-place" or "point-multiple-places" phase.	40
3.11	Input object generated by a "draw-area" phase.	40
3.12	Specification of a "draw-multiple-areas" phase.	41

3.13	Specification of the input object produced by a “draw-multiple-areas” phase.	41
3.14	Architecture schema for the Data Gathering Tool.	42
3.15	Examples of possible interfaces a “survey information” phase can have, with their different elements highlighted.	44
3.16	Interface for a question with a “choose-one” answer.	45
3.17	Schema representing possible paths a survey can follow, and design considerations to take.	45
3.18	Interface for questions with the answer types (from top to bottom) “number-input”, “select-dropdown”, “month-input”, “time-input”, and “choose-multiple”.	46
3.19	Interface elements for every map interaction state.	47
3.20	Interface for a “point-multiple-places” state. Note that users can place as many markers as desired.	48
3.21	Interface for a “draw-area” state, and an example of a polygon resulting from a drawn shape.	49
3.22	Interface for a “draw-multiple-areas” state. Note that for this particular case the user has already drawn “Alameda” and “Alvalade”.	50
3.23	The different elements on the dashboard interface.	52
3.24	The different elements on the analysis screen interface.	53
3.25	A possible analysis screen for a questionnaire phase. The fully visible graph corresponds to a question with a “number-input” answer.	55
3.26	Results for “month-input” and “time-input”.	55
3.27	A possible chart for results to questions of either “select-dropdown”, “choose-one”, or “choose-multiple” answer types.	56
3.28	A possible result of the processing of points into an hexagonal grid.	57
3.29	Available actions and configuration for “points” results.	58
3.30	The filter bar interface, and filter searching in detail.	61
3.31	Filters in filter groups.	62
3.32	The interface on the report screen.	63
3.33	The interface on the correlations analysis screen.	63
4.1	Variation of respondents that reached the different phases and completed them.	68
4.2	General distribution of participants.	69
4.3	Most used transports.	69
4.4	Where participants live.	70
4.5	Comparison of the distribution of meaningful places across different profiles. Green squares represent parks and large public spaces, blue circles are large malls, and the blue triangle is the college campus.	71
4.6	Comparison of the drawn areas representing the Lisbon each respondent is familiar with.	72
4.7	Agreement on Lisbon boundaries.	73
4.8	Box plots for drawn areas by all participants	74
4.9	Box plots for drawn areas by Residents and Immigrants, versus Commuters	75

4.10 Drawn areas agreement and area distribution, by long-term, and short-term, commuters and immigrants.	76
4.11 Agreement on Lisbon's historic areas.	77
4.12 Agreement on some of Lisbon's officially bounded parishes.	79
4.13 Comparison of the agreement on Bairro Alto, among different age groups.	80
4.14 Comparison of the agreement on Arco do Cego, among students and non-students. . . .	81
5.1 Variation of participants that reached the different phases and completed them.	84
A.1 General structures for both data objects.	91
A.2 General specification for "questionnaire" phases.	92
A.3 Specification of the different answer types.	93
A.4 Specification of the input produced by the different types of answers.	94
A.5 Specification of a "survey-information" phase.	95
A.6 Different input objects produced by "survey-information" phases	96
A.7 Specification of a "point-a-place" phase. Identical for "point-multiple-places".	97
A.8 Input object generated by a "point-a-place" or "point-multiple-places" phase.	98
A.9 Input object generated by a "draw-area" phase.	99
A.10 Specification of a "draw-multiple-areas" phase.	100
A.11 Specification of the input object produced by a "draw-multiple-areas" phase.	100

Listings

3.1	Algorithm for producing the “points” results	57
3.2	Algorithm for producing the “areas” results	59

Chapter 1

Introduction

For every mobile animal, structuring and identifying the environment could be described as a vital ability. From visual sensations of color and shape, to other senses such as smell and touch, many kinds of information affect this process. [Lynch, 1960] We humans, as part of this group of animals, also have our ways of perceiving surrounding space, and acquiring knowledge about it, as we act in the environment. This is called cognitive mapping, a process composed of a series of psychological transformations on the information an individual acquires about the relative location and phenomena in his everyday spatial environment [Downs and D.Stea, 2011]. It directly affects human spatial behavior, and has been shown to be fundamental to the efficiency of free-moving life, being used to get to destinations such as home and work, to give and interpret navigational instructions, to interpret maps, and more [Ishikawa and Montello, 2006].

After Tolman [Tolman, 1948] firstly introduced the concept of “cognitive maps” in his study as the mental image of space, and consequent behavior, of rats in the environment, the field of environmental psychology became increasingly interesting. Lynch [Lynch, 1960] presented one of the most relevant studies in the early days of this area of research, by using the concept of environmental image to evaluate the “legibility” and the “imageability” of the city, thus demonstrating the other side to cognitive mapping, environmental cognition: humans’ property of imbuing meaning and significance to a space, in addition to simple, objective spatial information. Many others [Milgram and Jodelet, 1976, Downs and D.Stea, 2011, Golledge and Gärling, 2004, Kitchin, 1994] contributed for this topic, corroborating the idea of people having the natural tendency of forming their own image of space, spatially and emotionally. Eventually, the concept of mental map grew wide and accepted.

A **mental map** is a direct application of the process of cognitive mapping to an everyday spatial environment, such as an individual’s city. It is a subjective, often fragmented and partial, representation of that city or area, emphasizing familiar and meaningful landmarks, paths, and locations, thus showing a close relation to one’s daily life and business. For example, a bus driver’s mental map would be quite detailed in terms of paths, while a child’s would be mainly built around home and school, and the way in-between. [Lynch, 1960, Jiang, 2013]

One can conclude, therefore, that, as well as this relation to daily habits, the shape, size, and detail

of mental maps, can also be influenced by many other things. Those can start from the environment's properties themselves, and end on a resident's personal characteristics. For example, depending on the exposure on mass media and social networks, an area's perception and feel can change dramatically. A resident's overall orientation will often be highly related with the amount of existent landmarks, and each landmark's scale. The type of transport used to get around in the city will be greatly responsible for one's view and feel of the locations crossed during that travel. And both social and economic conditions will enhance some areas, and degrade others, on an individual's mental map. [den Besten, 2008, 2010, Milgram and Jodelet, 1976]

Since differences in mental maps of a population can be traced to a certain cause, it's possible to select individuals into groups, where a city image is generally shared between members. One can even find, for most cities, a general consensus on the overall image, or collective mental map, among the whole population [Lynch, 1960]. All this offers a wide range of possible uses for discovering the mental maps of a target population. We see mental maps being widely used for psychological studies, trying to decode emotions and thoughts through insights on how people feel, or see, their everyday environment [den Besten, 2008, 2010]. It's for city development and planning, though, where mental maps show great practical use. After all, it's in a city-planner's best interest to find group images of the city, in order to better model the environment and contribute for an overall good image of the city in the minds of its population. Mental maps together with interviews, and/or geographical information systems (GIS), help gather multiple viewpoints of the city, display traditional knowledge, and reveal hidden spatial preferences and cultural meanings. [Brennan-Horley and Gibson, 2009, Matei et al., 2001, Rambaldi and Callosa-Tarr, 2000, Sulsters, 2005, Cranshaw et al., 2012]

The great majority of studies on mental maps, whichever the use for the results, usually adopt the "sketching method", which consists on asking the participant to draw from memory the an area's map [Lynch, 1960, Bentley et al., 2012, Milgram and Jodelet, 1976], while others turn to coloring or marking maps, in order to, for example, know how a person feels in relation to the different areas of the city [Matei et al., 2001, Brennan-Horley and Gibson, 2009]. These two approaches, while the most accurate and data-rich, make it difficult to both gather and analyze a large number of individuals' mental maps, which is the most important feature for large surveys such as the ones for urban planning. More recently, some studies got around this problem by starting to directly use digital technology to gather and treat mental maps¹ [Cranshaw et al., 2012, Del Bimbo et al., 2014, Imbe et al., 2010]. However, either the tools aren't open for everyone, or not flexible enough for satisfying every researcher's needs, and thus there is no *de facto* tool to simply create and analyze a mental maps study, whichever the city or population.

We propose to fill this gap by implementing our own solution: **Semantic Cities**. A complete framework that offers the due tools to easily create and publish a proper survey, and to analyze its results. The goal is to simplify the process of gathering and analyzing mental maps. With an appropriate number of participations, a researcher should be able to quickly identify collective mental maps, by filtering and manipulating the data as freely as possible.

From the start, the customization of the survey is seen as one of the most crucial element of this

¹See "Mapping Greater Boston's neighborhoods" (<http://bostonography.com/2015/map-your-neighborhood-again/> visited on 12.05.2016)

framework, right after its effectiveness. Therefore, the easy adaptability of the study to any place or population, regardless of scale, is put first in our implementation. In order to reach such output, the first step to take is to study the most effective set of tools and functions with which we can find a population's mental map on a non-interpersonal manner, as is the approach of this work.

After that, we must define a virtual representation, or notation, for the data to present on the survey. That way, functionality could be more independent from the data, and it would be possible for our framework to generate a survey just by "reading" such data. In other words, we can separate the *how* from the *what*.

The next step is to create the two different interfaces: one for answering the survey, and another for analyzing the results. Both should be carefully tested in terms of usability, but the interface to participate on the survey needs special attention. Would a user face any problem or difficulty during his participation, he would most likely give up halfway, and make the researcher lose potentially valuable data for his future study. Thus, we must struggle to make this interface as simple, usable, and fool-proof as possible.

At last, we evaluate the overall framework, both on a technical level, where the intercommunication of its different parts is of most relevance, and on a conceptual level, where we should validate the usefulness and effectiveness of the implemented tools by analyzing the results from our own created survey.

1.1 Objectives

One of the first decisions regarding the outcome of our work is the flexibility as a priority. It aims to offer any researcher, professional, or enthusiast the possibility to find the different mental maps towards any area of their choice. That flexibility must also be present when analyzing the data, in addition to its gathering, since the author of the study should be able to, as much as possible, filter and manipulate the data to test his hypothesis. Of course, as important as flexibility, we must ensure that any gathered data is useful and interesting. Thus, we can state our main objective as:

Create a set of digital tools that, together, provide a complete and customizable framework for finding a population's mental maps towards any area

From this, we can also state secondary goals to achieve during the making of our project. The first is to **create a website, to host the online survey**, which in turn implies the need to **identify the necessary features to find a participant's mental map**. Then, we should offer the researcher the possibility to create his own survey by **creating a way to simply specify and create a survey**, allowing the creator to **pick whichever features, and arrange them in any order, as needed**. Finally, we must **build an application for analyzing the results of the published survey**, which in turn requires us to **find all the possible ways to filter and manipulate the data from the survey participations**.

As stated before, the success of our project depends on the validity of the data gathered by the survey. In order to evaluate this, we need to see how effective is the functionality available for the survey. Thus, we intend to run a test case, creating our own survey to find the different mental maps for Lisbon's neighborhoods. This case, therefore, has its own objective:

Find the different mental maps of Lisbon's neighborhoods

And it also comes with its own share of smaller, secondary objectives. The most trivial, is **the use of the results to validate both the features and interface of the survey**. Also, we should also use the case study to run a study ourselves, and thus draw our own conclusions on **how one's mental map is influenced by his daily-life and residence**, and also on **how much does a mental map change between varying personal backgrounds**.

1.2 Contributions

The main contributions of our work include:

- Scope and requirements for mental maps digital surveys: where we list and explain each feature that any effective mental maps survey should include
- A digital notation for mental maps surveys: a way to specify such a survey using only JSON specification
- An interface for mental maps digital surveys: a set of files ready to be loaded to a web server, freely and openly available at GitHub
- An analyzer of mental maps digital surveys: a set of files ready to be loaded into a web server, freely and openly available at GitHub
- A study on the mental maps of Lisbon

1.3 Structure

The next chapter will list, analyze, and discuss, the published works in three areas: Subjective Data Gathering, Data Driven Approaches, and Environmental Psychology. Chapter 3 will explain the whole process of the creation of the framework, separated into each of its parts, which in turn includes the planning phase for each of them, and their implementation. In chapter 4 this work describes a case study on the city of Lisbon, reporting the decisions made in its creation, and analyzing its results. Chapter 5 concerns the evaluation of the framework's effectiveness. Finally, chapter 6 concludes this thesis with a brief summary of the work and the resulting conclusions, ending with some suggestions for future work on the subject.

Chapter 2

Related Work

In this section we list and discuss previously developed work, which helped us both before and during the making of this project. We separate it into 3 sub-sections. The first is concerned with studies in the field of environmental psychology, needed to understand what a mental map is and what affects its form. As for the second and the third, they list projects which aimed to understand the differences in each person's space behavior and perception, i.e, they weren't necessarily preoccupied with the concept of mental maps. The most important aspects we looked for were, then, if there was a gathering and analysis of collective geo-spatial data, and their conclusions. The difference between these two sub-sections relies on their approach to their work. **Subjective Data Gathering** concerns projects where the used data was gathered in some personal, or subjective way, and it can range from interviews, to digital surveys. **Data Driven Approaches** on the other hand, opt for the automatic and massive collection of objective data — like location in a certain time — then looking for patterns in it.

More specifically, we searched for projects that fulfilled at least one of the following characteristics:

- Evidence on the existence of mental maps, and their differences between each individual
- Exploration of the influencing factors on people's mental map
- Exploration of the differences in the mental maps between groups of people
- Exposure of the differences in quotidian habits, regarding some factor

Next, we list the most relevant results of our search, separating them into three different categories based on the previously stated differences.

2.1 Environmental Psychology

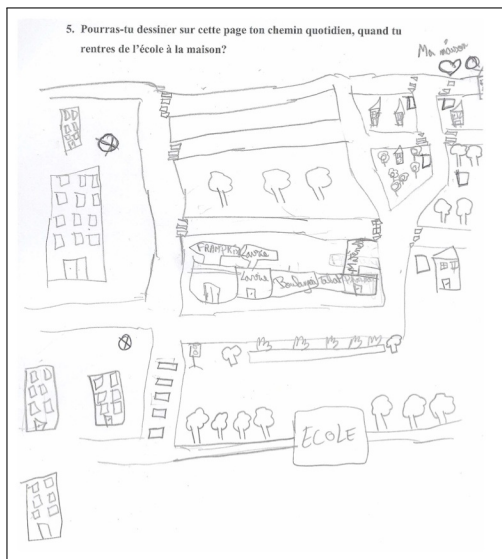
“Environmental Psychology” is how we categorize any study that focuses on the psychology under mental maps or spatial behavior. The ones we focused on are those who try to find the relation between a person's mental map and her personal conditions, such as social status, quotidian habits, *etc.* Thus, projects exposing these aspects, along with those which focus on non-personal influences, are crucial

for us to figure out how should we design our tools. With them, we can reliably find both the best way to gather meaningful data, and the best way to analyze it.

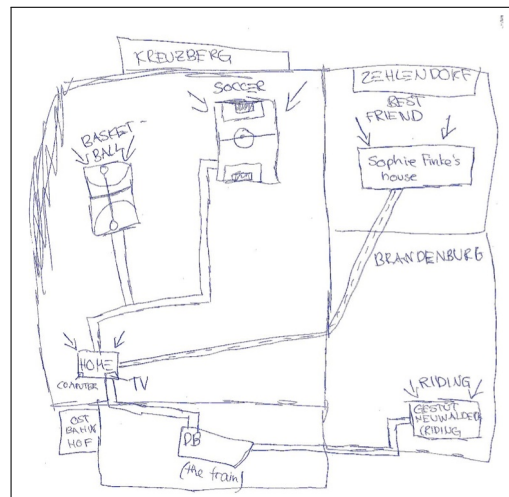
2.1.1 How Immigrant Children Experience and Picture Their Neighborhoods

Emotions and experiences affect our perception of space, but is it possible to see how affected it is? “Mapping Emotions, Building Belonging: How Children with Different Immigration Backgrounds Experience and Picture their Parisian and Berliner neighborhoods” [den Besten, 2008] explores this topic by analyzing the mental maps of immigrant children residing in Berlin and Paris. The main goal is to understand the feeling of belonging to the new city and culture. To do this, the author asks the children to draw maps, in order to reveal significant references in the everyday life of the child in question.

It was asked to draw two different maps: a representation of the daily home-school commute, Figure 2.1(a), and their neighborhood plan, Figure 2.1(b). Children were also asked to include personal *emoticons* to reveal their favorite places (a heart), the disliked areas (cross inside a circle), and feared areas (marked with a square).



(a) Sketch of the path from school to home



(b) Sketch of a child's living area

Figure 2.1: Used techniques to understand children's subjective maps.

The results clearly show the existence of objects of reference, or landmarks, in each child's mind, such as certain buildings and green spaces. These led the structure of every map, and everything else was left with a much lower level of detail. The drawn landmarks reflect the experiences of each child; they are icons of children's feeling of belonging to their city area, because they reveal a feeling of special connection to them. There are also negative areas, which were also in much less or no detail at all, and these relate either to a feeling of fear towards them (sometimes due to induced prejudice), or to a lack of engaging activities in them.

Therefore, the study exposes two interesting aspects. The first is the relation between a person's space perception and her feelings, experiences, and conditions. Second, is the usefulness of the mental map to show those relations.

2.1.2 Mental Maps of San Francisco

Beyond personal experiences and conditions, a city's own design and plan influence its population mental map. "Visualizing Mental Maps of San Francisco" [Annechino and Cheng, 2011] explores this aspect by encouraging each participant to reflect on his own, and others', perception of neighborhood and city. It collected data from 22 semi-structured interviews, and each participant's sketch of his neighborhood and San Francisco's map. The answers were categorized among the following: orientation, corridors, barriers, and borders.

The authors made some important observations on the results. The first, under the "orientation" topic, is that people didn't follow the "north orientation" on their sketches like a normal map would do; instead, some drew their maps with the east on top, others with the west, etc. This can be traced to a person's sense of direction, differing completely among each individual and following no abstract rules: some use landmarks as guidance, others use the ocean as reference point, and there are some who deeply rely on public transport to find their position.

"Corridors" appeared naturally in many sketches, as most participants saw the city as a limited group of relevant corridors. Each of those would have at least one depicted point of interest, usually related to commerce, or personally relevant space, and the rest with little or no detail, once more showing the relation between space perception and habits.

"Barriers" were mostly identified in the interviews, and as the expected obstacles to someone that relies on walking or bicycle to get around, such as hills and highways. Figure 2.2 we can see those barriers mapped into San Francisco: darker areas representing hills with an high level of slope, darker lines representing roads with higher speed limit. While the barriers weren't explicitly drawn on the sketches, the authors were able to establish relations between them and the detail of the sketches, showing how one of those barriers can limit a neighborhood's perceived area, or the knowledge about some space.

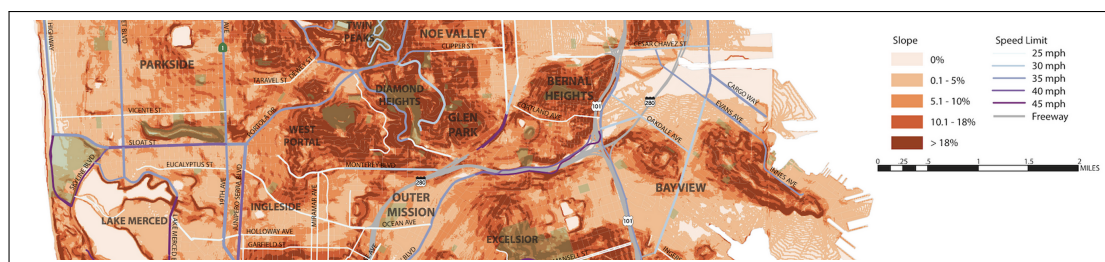


Figure 2.2: Map of the hills and roadways of San Francisco.

Under the topic of "borders", the authors found that every resident knew some neighborhood boundaries very well, these being the more famous and traditional ones, like Mission. As for the rest, the results show how ambiguous boundaries can be, since even those who say to belong to a certain neighborhood, can't correctly define its boundaries.

From this study, we should retain how the city itself influences the space perception of its population. Barriers and corridors, in particular, show how well designed a city is, the fewer the first and the more of the second, the better. Furthermore, its also shown that perceptions on borders and orientation seem to be more related to the city's history and geography. Such insights are useful for validating our ideas and

product features, and for guiding our conclusions on the case study.

2.1.3 Different Perceptions of a Place Brand

Nowadays, cities try to promote themselves in order to attract tourists, business, and new residents. To achieve it, much of the time, place marketers try to describe the city as a brand to better reach the audience. However, by its definition, a brand is a network of associations in consumers' mind, subjective to each person or social group. Addressing this problem of generalization, Zenker et al. [Zenker et al., 2010] gather Hamburg's city perception of more than 350 participants to expose the differences in perceived brand by group.

Two separate studies were done: 40 in-depth interviews with two focus groups, and a public online questionnaire. Both focused on finding image associations with the city brand, although the first took a more qualitative form, in contrast with the quantitative ways of the second. This mixed method allows both to capture the unique associations of the target group members and to translate it into a comparable brand perception structure in a reliable manner. The first study focuses on two important groups for place marketing, the creative class (artist, scientists, urban planners, etc) and students, each represented by 20 people. The second study, being available to anyone, tries to reach both residents of Hamburg (internal target audience) and the rest of the world (external target audience). The results consist of a network of brand associations, comparable with the perception of the other target groups, where the aim is the identification of brand associations strongly connected with each other.

Regarding the first study, the resulting top 20 core associations for each group, shown on Figure 2.3, reveal some differences that can be related to the kind of importance that each group gives to each aspect of life in Hamburg. This is particularly clear for students, where there is a greater occurrence of activities related with university or leisure time, such as bars and restaurants.

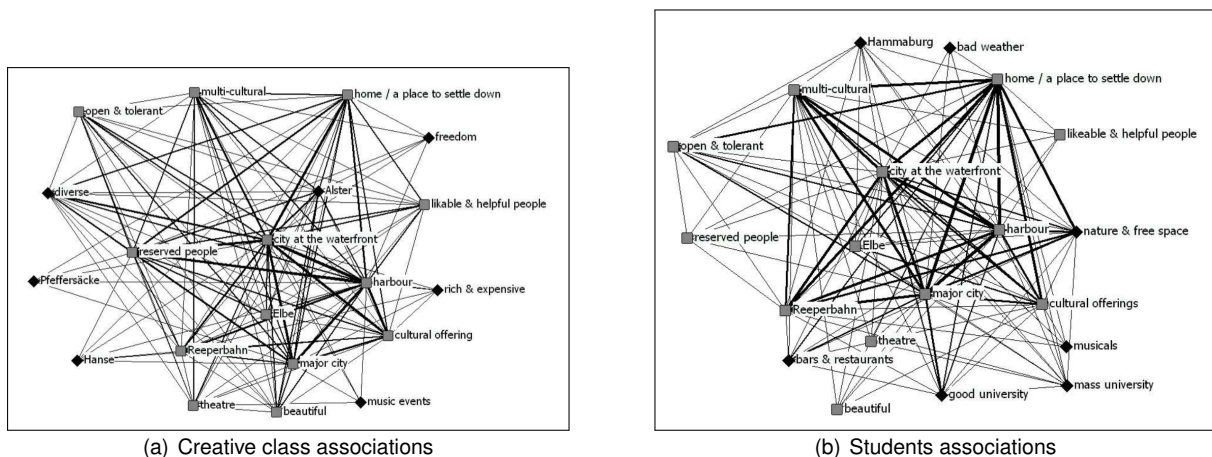


Figure 2.3: Resulting association network from interviews.

In addition to image associations, the online questionnaire asked the familiarity that each participant had with the city of Hamburg, resulting in two categories: the current or past residents of the city representing the internal target group, and the ones who never went or only made a brief visit to Hamburg, the external target group. The results, Figure 2.4, show how heterogeneous the view from Hamburgers

can be, when compared with the external group stereotyped homogeneous picture of the city. A good example is the top association “Ocean”, made by the external group and seen in Figure 2.4 (b), even though Hamburg is located more than 100 kilometers away from the Atlantic ocean.

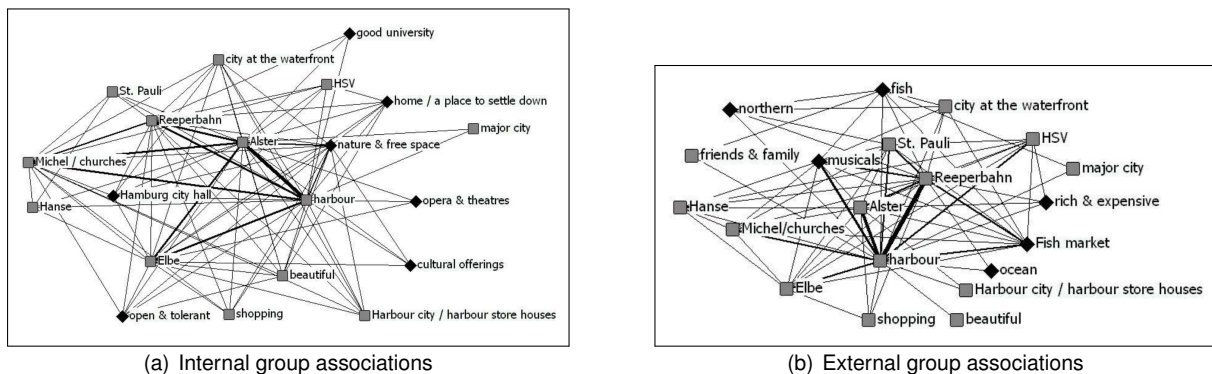


Figure 2.4: Resulting association network from online questionnaires.

This work reveals the natural association of certain ideas with spaces, and how those ideas change within different lifestyles and experiences. Furthermore, it shows how someone strange to a certain space has his own preconceived thoughts about it, which can be applied to a case like a neighborhood's resident ideas towards another neighborhood, something of interest for our work.

Although there is no exploration of mental maps, this work proves that, even without such technique, it is possible to understand a population's perception around a given area, helping us choosing the framework's tools.

2.1.4 Psychological Maps of Paris

A mental map, while always unique to each one, can share some aspects between members of a certain group. “Psychological Maps of Paris”[Milgram and Jodelet, 1976] tries to find these groups by examining Parisian's mental representation of the geographic reality of Paris, or put simply, by exploring their mental map of the city. After a 4-phase interview was made, the results were matched with each participant's personal information, and then compared with other participations for patterns identification and other conclusions.

The first phase of each interview consisted on sketching a map of Paris, which, in the end, represented the participant's own view of the city. The results of this method revealed a first set of important city references, in addition to the general orientation of the participant. As highlights, the authors pointed the choice of first drawing the city limits, then the Seine river (which, in general, assumes a very different shape from the official one — see the dashed in 2.5), followed by historic monuments and places, and, finally, some few connections between such public spaces and the more personal space of the participant. Based on these outcomes, the authors concluded that Parisians learned the map from official ones, and showed reasonable knowledge of the city's general organization, revealing that street maps of Paris are an inherent part of their culture; however, by processes of selectivity, emphasis, and distortion, the maps became projections of the life style and emotions of each subject. Furthermore, since city limits and the Seine are drawn first, these can be identified as the basis of Parisians' general orientation, even though

the river never met the correct representation in the sketches, the general shape of slightly curved line revealed the habit of walking alongside it. Turning to the most drawn buildings and their corresponding order of appearance in the maps, subjects make it clear about the importance of the historic center, since among those buildings and places are the “Notre Dame” and “Île de la Cité”; from this, rises the observation that Paris has a strong and well defined psychological core, defined by its historic center. It was also noted a great agreement around what elements were included in the sketches, consisting of all the touristic landmarks, and it shows how integral the French capital is for its inhabitants. And even though Parisians insist that there is a tourist Paris and a “real” Paris, the authors state that no intelligent person, local or tourist, could represent their view of Paris without referring such landmarks.

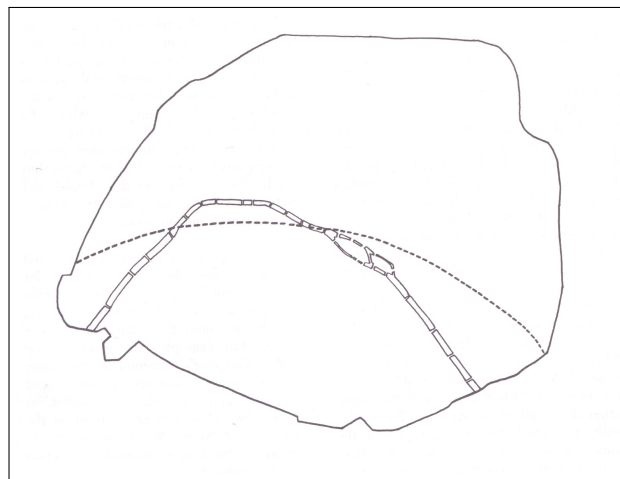


Figure 2.5: Average distortion (dashed line) in the mental representation of the Seine.

The second step of the interview consisted in discovering interviewees’ psychological links between city references, a way to see how several elements in the subjects’ mental structure of Paris were held together. Participants were presented several monuments or historic places, and asked to say which other monument or place they thought of when confronted with it. The answers were gathered into a table, showing how many different elements (referenced by more than 10% of the participants) were associated with each “stimulus locale”, Figure 2.6.

Next in the interview, people were presented with photographed scenes of Paris, and asked to identify them. This technique was used to test the real importance of those urban visual aspects to a person, seeing if she can match an external stimulus to some memory of it. Correct recognitions show that a scene is an active part of the subject’s city perception, even if he did not spontaneously include it in the map.

Finally, to gain a more general picture of the known and unknown parts of the city, the participants were asked to identify 10 *quartiers* – Parisian administrative districts – with which they were more familiar, and then the 10 they knew the least. The general picture showed a very concise result regarding the 10 best known *quartiers*: they were all from Paris historic center. When turning to the least known areas, all of them in Paris suburbs, there was much less agreement, though following a certain pattern: social segregation. Paris south-west suburbs were always known as a more rich zone, where the majority of the business class lives, while the working class usually lives in the north and east of Paris suburbs.

<i>Stimulus locales</i>	<i>A Number of locales with which stimulus locale is linked by 10% of the subjects or more</i>	<i>B Percentage of subjects who fail to link stimulus locale with any other locale</i>
Arc de Triomphe	6	.5
Notre Dame	6	1.8
Place de la Concorde	6	1.8
L'Opéra	6	2.3
Sacre Coeur	2	2.3
Le Louvre	4	3.7
Tour Eiffel	5	5.1
Gare St. Lazare	1	5.5
Bois de Vincennes	3	6.9
Porte St. Martin	2	11.0
Le Panthéon	6	11.5
Tour St. Jacques	4	12.4
Place de la Nation	2	13.3
École Militaire	3	13.8
Place de la République	2	16.1
Lion de Belfort	3	18.4
Parc des Buttes Chaumont	0	20.2
Place d'Italie	3	22.5
Père Lachaise	0	27.0
Parc de Montsouris	1	34.0

Figure 2.6: Mental links to each stimulus.

Therefore, participants belonging to the second zone, identified south-west *quartiers* as the least known areas, and vice-versa for participants with higher levels of income.

The authors make a very interesting approach to the problem of discovering the mental map of a population towards a city, since they explore people's subjective view, and relate it with some of their personal characteristics - ranging from the living area to their income level. This way, the work identifies some patterns that reveal some of the psychology behind a person's construction of her mental map, including the influence of the city characteristics themselves.

2.1.5 Investigating suburban environment by means of mental maps

This project [Biolk and Andrásko, 2015] applied the mental maps methodology to the study of suburbanization in Oloumouc, Czech Republic. The authors were curious to see how people saw suburban regions that were recently built, and test if there was any difference between new residents and old denizens, and thus used mental maps as an instrument to examine the character of the suburban environment, its perception by local inhabitants, and their experience to the place of living. Their overall aim, however, more than analyzing the results, was to test if mental mapping was an effective tool to evaluate the environment of the suburban municipalities.

To do it, the authors asked respondents to freely sketch out the target municipality, their place of living and important elements inside the same spatial context. Furthermore, to find correlations, they also asked for their age, gender, social status, and whether they were new residents or denizens from before the recent suburban developments.

As the process called for the sketching mental mapping without strict instructions, it made it easy for participants to show their opinion or mental image of space, but impossible to quantitatively compare

the drawings. As such, the authors used a clever approach to, instead of direct comparison, evaluate qualitatively each participation.

In a table, they accounted for the number of elements in each drawing, the number of borders, the character of the drawing (between scheme, picture, spatial, sequential, *etc*), while also displaying all the other gathered info on each participant's background.

The resulting sketches mostly followed a schematic approach, not exactly representing space, but rather a series of mostly written directions and elements, think lines and shapes.

Most people included several of the same type of infrastructures and public facilities, like the church, pub, shop, roundabouts, and bus stops. Also, they all included their houses, and some included more personal elements, such as schools and kindergartens. This contributes to the reigning theory of dominant elements that contribute to a shared, well-formed spatial image among the population of the target place. Against most research, though, no differences were found when comparing participations by their different background information.

The authors conclude that mental maps can easily show a population depict a municipality, but that it's still very difficult to compare them, and thus form conclusions.

2.2 Subjective Data Gathering

This section summarizes every relevant related work on "Subjective Data Gathering". This type of projects are focused on collecting **subjective views on space**, usually consisting in personally asking specific questions, and testing hypothesis against that data.

There are, however, some other approaches which explore the differences between mental images of space with the help automated tools, such as an online questionnaire. Projects that follow that path are what interest us the most, helping us understand how to take on the challenge of comparing highly variable, mostly qualitative, subjective data in an automated way.

2.2.1 Boston's Crowdsourced Neighbourhood Boundaries

"Neighborhoods as seen by the people"¹ has the goal to observe people consensus on the boundaries of Boston's neighborhoods. To achieve this, the authors developed a web application which asked people to draw the boundaries of each official neighborhood of the city. The answers were then displayed on top of the city map, and as a result participants' agreement on the area of a neighborhood was revealed. Finally, the authors tried to find patterns in the results, relating them to several characteristics of the city.

The project was made of a large number (over 950) of participations on a custom survey software² where, under anonymity and providing no personal background information, respondents drew on top of Boston's map, using free form polygons, boundaries of its several neighborhoods. The results were displayed in a per-neighborhood basis where different colors represent different levels of consensus. For this step of the project, the chosen levels were 25%, 50% and 75% of agreement and each one respects

¹Last visited on 22.06.2016 at <http://bostonography.com/2013/neighborhoods-as-seen-by-the-people/>

²Last visited on 22.06.2016 at <http://bostonography.com/neighborhoods/>

a certain intensity of blue color (lighter for weaker agreement, and darker for stronger agreement), as seen in Figure 2.7. For that figure in particular the differences between opinions are remarkable, showing how much differently each person can imagine a neighborhood area. The author explains this phenomenon, stating that the neighborhoods are not defined by their edges, or by what it's outside of them, but by their contents, ranging through shared history to architecture and culture.

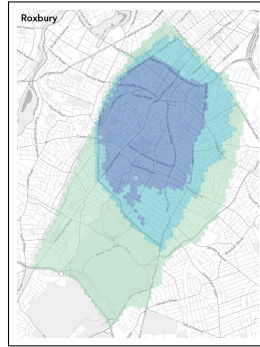


Figure 2.7: Survey's results on the neighbourhood of Roxbury

In a later article³ by the same author, a re-iteration on the results was made, which differences between the first can be seen in Figure 2.8. With that great volume of data, it became possible to find several phenomenons. There was general agreement on all the old, central neighborhoods, as observable on the upper-right zone of both maps on Figure 2.8. This comes as predictable, due to their tendency to have distinctive visual identities, such as monuments. As for the other newer, residential neighborhoods, the borders are far less clear, even when there are real historical boundaries.

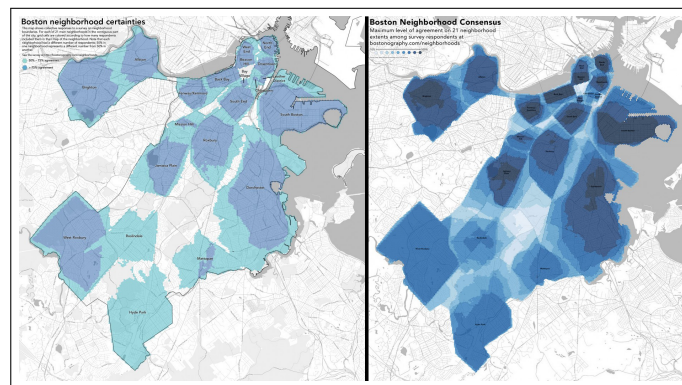


Figure 2.8: The initial (left) and final (right) phases of the survey. For both maps, the darker the area, the more agreement in it.

This project showed off an automatic tool to gather subjective data, as the spatial perception is, from different people. However, it didn't leave space for many conclusions. By not asking for any personal information, it is not known where the respondents live, or even if they come from Boston, eliminating the possibility to observe several crucial patterns between a person's perception about an area and her personal background, which could then be related to the city's design itself.

More recently, the authors created a new version of the boundaries drawing tool⁴ in the hopes of

³Last visited on 22.06.2016 at <http://bostonography.com/2013/neighborhoods-as-seen-by-the-people/>

⁴On <http://bostonography.com/hoods/>, visited on 23.06.2016

overcoming some flaws of the first. This new version lets users freely draw on the map (instead of the old vertex-to-vertex way), asking them to provide the name for that area themselves. In addition, for every drawing the participants submit, they are asked for how many years they have lived in that neighborhood, if ever, and in the city of Boston, this way providing more insights to the validity of the drawn area. Furthermore, participants were presented with the option of, instead of drawing boundaries, placing a marker in a certain place, building, or monument which they felt as the “crucial point” for the neighborhood in question. This makes it easy for more people to participate, and exposes other important aspects on how people see the city.

This new version brings much improvements over the older. The most relevant feature, however, is how the survey now asks for personal information. A bridge between the participant’s knowledge and the results was made, patterns are now more reliable, and one could even compare, for example, the difference in opinion between residents of a neighborhood and outsiders.

In sum, Boston’s Crowdsourced Neighbourhood Boundaries reveals several ways on how we can approach this issue of finding mental maps, and more important, it describes the potential for digital solutions.

2.2.2 Mental maps applied to the coast environment

This work [Gueben-Venière, 2011] was developed to both evaluate a mental map collection tool and to understand how different group of experts imagine the boundaries of the coastline.

When collecting spatial representations using mental maps, the authors admitted the existence of two options. Either allow a sketch of the space in question in a blank piece of paper, or showing instead a basic map containing only the space’s outline and critical points. In this case, a basic map of the Netherlands was provided, with only its borders and main cities included. This, according to the authors, greatly facilitates the later compilation of results, as they become comparable and quantifiable.

The conducted study aimed to collect the limits the interviews would give the coastline, determining how far they extend it inland and out to sea.

To complement the drawings, it was conducted a semi-structured interview where firstly interviews were asked to provide a verbal definition of ‘coast’.

The drawn-up maps were gathered and scanned into an appropriate GIS program, where it would calculate the superimposition of the drawings, thus permitting an establishment of an “average” mental map.

The results for a first group of respondents, 14 engineers, are shown in Figure 2.9. There, it can be noted that the majority of them included underwater volumes. Not only that, 8 of them also highlighted inland areas as being part of the coastline, and thus showing the perception of a coastal area when talking of “the coast”.

A second group of interviews, conducted with 8 ecologists and other scientists, showed, on average, similar results, and thus a similar perception.

The authors were happy to note the effectiveness of their tool and method to uncover different per-

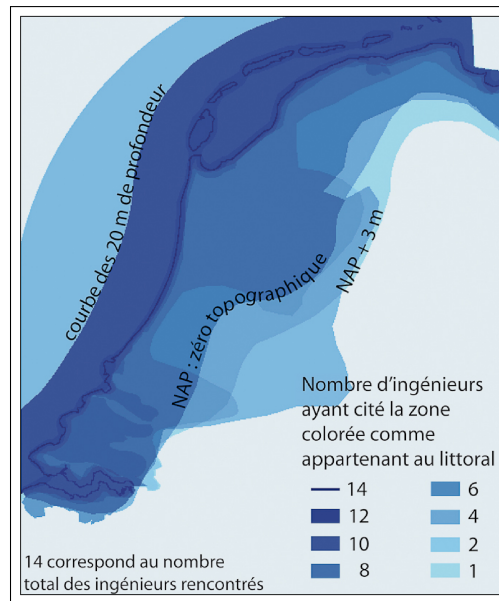


Figure 2.9: The limits of the coast of Netherlands, according to 14 engineers.

ceptions among groups, being able to visually and quantitatively compare them. They noted, however, how important the complementary interviews were, to better understand the views beneath the “drawn opinion”, and thus pointing background information as a crucial point to consider.

2.2.3 Psychological Maps of London

Motivated by the suggestion that the recognizability of the urban environment is linked to people’s socio-economic well being, Quercia et al. Quercia et al. [2013] developed a web game to test the recognizability of London’s streets.

The game consists of several rounds, and in each one, it confronts users with 10 different *Google Maps’ Street View* images, asking if they can guess the location where the photograph was taken. The location could be specified in terms of closest subway station, borough, or city region. The aim was for answers to be easy to give, justifying the use of subway stations, the most widely used reference points, and the limitation for pictures’ location to a 300 meter radius from one of those stations. At the end of the game they are also confronted with a small questionnaire to gather some personal data (sex, age, residence location, etc). After 2255 contributions, a London map was properly distorted according to the recognizability of each borough, Figure 2.10 shows the result, the biggest areas being the more recognized ones.

The author ends up finding that the major influence to a borough recognizability is its exposure to subway passengers, even though the number of iconic monuments, and the borough’s presence on image and location services, such as Flickr and Foursquare, did show some influence over the results. Beyond such findings, the author observed no relation between recognizability and participants’ socio-economical well being, but discovered that boroughs with high crime rates and poor living conditions had a very low recognizability.

This work thus shows us the importance of the transport and a person’s spatial image. Being one of

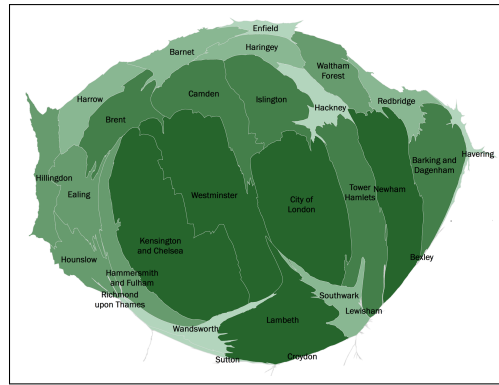


Figure 2.10: Map of London with each region distorted by its recognizability.

the few constants in the daily life, transportation between well known places (such as home and work), and the path between them, takes an important place in each one's mind. It is then crucial for us to enable, in our framework, the exploration of how the target population gets around.

Furthermore, and even though the project doesn't focus on mental maps directly, it shows how much we can discover about them with simple approaches like these, and thus clues us in on how to design our platform.

2.2.4 Drawing the City of Chicago

"Drawing the City: Differing Perceptions of the Urban Environment" [Bentley et al., 2012] aims to explore Chicago's mental map of different people, relating the results to each respondent's personal background and, mainly, his use of location technology. To reach this, the authors made three approaches: one based on the work of Milgram and Jodelet [1976], relying on participants hand-drawn city maps as the subjective perception of the city; other consisting in asking for a personal opinion on different city areas; and finally a questionnaire to further explore the background and technological habits of the people in question.

A table was set in one of Chicago's most famous parks to easily attract both tourists and locals. There, people were asked to, first, draw a map of what Chicago was for them, giving special focus to places meaningful to them. After that, a blank city map was shown and they were asked to both identify the city's neighborhoods, and to characterize certain areas (e.g: as dangerous, as good for dinner, as feared, etc). At last, participants completed a questionnaire on their personal background, on how they use location-based technology, and about the frequency of use for each type of public transport.

From the hand-drawn maps, the authors logged the represented elements of the city, the percentage of the city area covered in the map, the included neighborhoods, and the types of places listed (based on Foursquare's venues categories). As for the filled blank map, they mainly focused on which neighborhoods/areas were considered as dangerous.

The results showed some surprising data on the subjective representation of the city since that, across every group (elders and young, wealthy and poor, etc), the type of maps drawn presented a lot of similarities. They showed varying details in certain areas, but reference points were about the same,

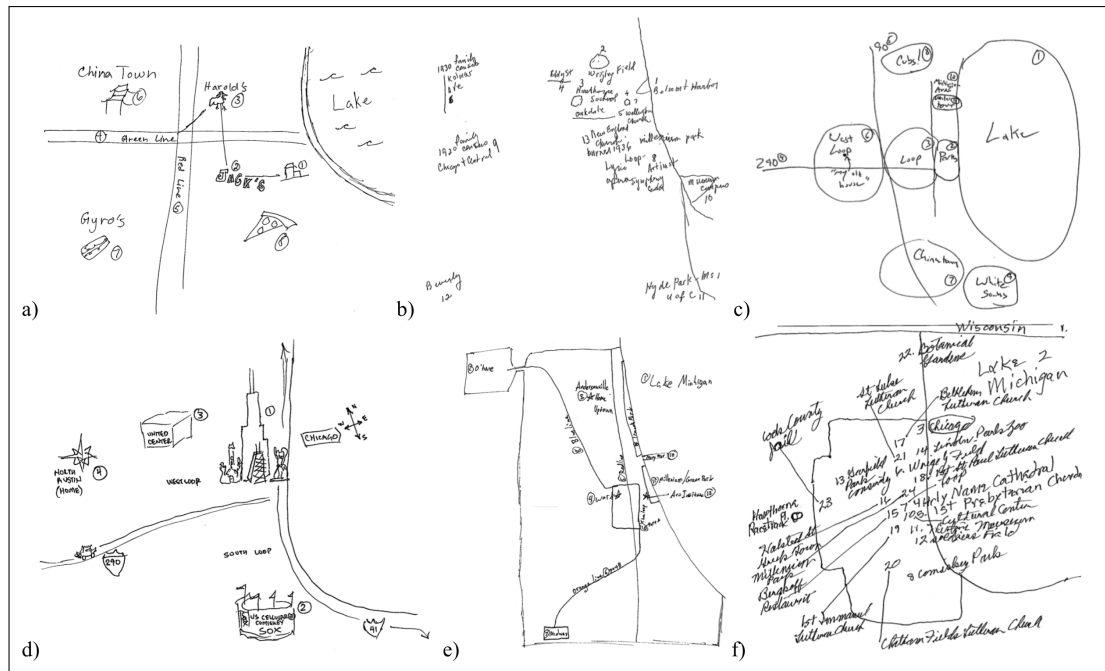


Figure 2.11: Different drawings of the map of the city of Chicago.

and both the general view and the orientation of the city were maintained, see Figure 2.11. Those same maps, however, detailed only small percentages of the city (an average of 5.3 neighborhoods in a possible 95) and the second approaching method did not reveal much more knowledge on that, considering that the average participant highlighted only 11.5 neighborhoods. As for tourists, they included almost no official neighborhood names and were twice as likely to make pictorial representations of buildings and landmarks (representing their touristic view of the city).

Crossing the previous with the data from the questionnaire in order to better understand the population's perception of the city, the authors found that users of mobile location services, who regularly use different types of transport, are less likely to identify neighborhoods as dangerous, being only behind residents of those same neighborhoods. This goes against the ones who drew more detailed maps, identifying several dangerous and feared zones.

This study implements good methods to retrieve subjective data, and relates perception of space to personal characteristics. Although the curious observation that people with so different backgrounds drew the same type of city maps, there still is evidence that a perception of a city differs between each individual. Particularly, it's clear that the "feel" about a certain area is heavily influenced by both the person's background and habits, as we can see by the results about the danger felt on different neighborhoods. Benefits of location-based services on the knowledge of the city are also revealed, reminding to take such habits into consideration in the analysis of retrieved data.

2.3 Data Driven Approaches

In this section, we present projects that follow "data driven approaches". Such type of work usually focuses on the gathering of massive amounts of objective, as in non-subjective, data (e.g: points in

space). Conclusions are then left to whatever patterns emerge from those clusters.

Many of the described projects don't relate to mental maps, but still, along with the rest, reveal patterns or influences in space behavior that will be useful to take into account when picking the framework's tools.

2.3.1 Twitter Languages in London

"Top 10 Twitter Languages in London"⁵ represents, on a London map, the different languages used by the city's population when posting content to Twitter. This was done using both Google Translator algorithm, to detect the languages, and Twitter API to detect tweets positions, during the summer of 2012.

Most of the tweets - 92.5% -, as expected, were written in English, and are represented as gray dots on Figure 2.12. As for the other most *tweeted* languages, they've pointed Spanish, represented in white, French (red), Turkish (dark blue), and Arabic (in green). Looking into Figure 2.12, we can see that the tweet geographic distribution respect some patterns, the clearest being concentrated tweets of the same language, representing neighborhoods mainly populated by a specific ethnic group (e.g. Edgware Road for arabic tweets).

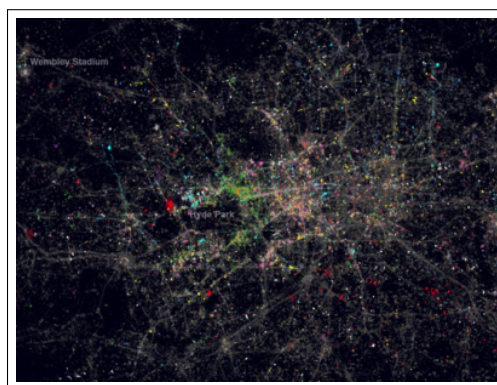


Figure 2.12: *Tweets'* languages in London.

Though it does not present any significant thoughts on the results, this work ends up showing how people from the same culture tend to cluster themselves in the same area or region, thus potentially uncovering interesting patterns. A possible example is that people who do not belong to a certain community are ignorant of the same community-specific areas, affecting their mental representation of the city's geography. It thus shows how important it is for a mental maps study to have access to data on the cultural background of a person, and, in general, her many personal characteristics.

2.3.2 Where The Tourists Really Flock

"Where The Tourists Really Flock"⁶ sets as goal the differentiation of a city's locals and tourists spatial habits. The author starts by collecting the geographic information of the *Flickr* photos taken in a certain

⁵Last visited on 12.10.2016 at <http://twitter.mappinglondon.co.uk> and <http://www.visualcomplexity.com/vc/project.cfm?id=777>

⁶Last visited on 03.10.2016 at <http://flowingdata.com/2010/06/08/where-the-tourists-really-flock/>

city, associating each picture's author to one of the groups, local or tourist. This separation is possible due to the following distinction: tourists are those to have photos tagged to the same city only during a limited amount of time of one month or less, usually tagging their pictures to a different region; locals have different pictures tagged to that city dating over a month between them.

Some of the resulting maps can be seen on Figure 2.13, where the blue points represent the locals, and the red represent the tourists. There are also yellow dots, representing inconclusive cases, usually for users that don't use *Flickr* enough times to know for sure where they live. These images show that photo agglomeration does not necessarily mean a great flow of tourists, locals have their contribution too, sometimes avoiding those same tourist attractions and photographing less famous areas as the suburbs, see the case of Paris (Figure 2.13(a)). As for the map of Lisbon, Figure 2.13(b), we can see the different hot-spots for travelers and the more modest, residential places being captured by locals.



Figure 2.13: Resulting maps by locating the photos taken by tourists, in red, and locals, in blue.

This project shows us yet another creative and automatic way to obtain spatial thinking data, this time revealing some possibly interesting scenarios such as locals' quotidian habits leading to avoidance of tourists' crowded areas. However, the author does not compare the results with, for example, surveys to collect subjective data, avoiding a validation of the previously described scenario. Nevertheless, it represents an interesting and credible pattern to relate to some shape of a mental map, and something to consider exploring in the making of our framework and our case study.

2.3.3 Cities Pulse via Foursquare Check-ins

Foursquare's team made the study "Cities Pulse via Foursquare Check-ins" to understand a city's pulse. According to them, a city's pulse consists of how the city life looks like on an average day. By reaching such goal, it would be possible to identify activity-specific areas of the city, like, for example, nightlife areas, as represented in Figure 2.14(b) which represents New York check-ins in the nighttime.

To do this, the authors simply used Foursquare's API to retrieve users check-ins during an entire year. Then, they animated the connection between the different places visited by each user, adding

movement to otherwise static points - these represented travel or commute activities, something that Foursquare does not directly support. Check-ins, the action to share the current location to the network, were already divided into specific categories, and were then color-coded accordingly. To better identify the pulse, authors also calculated, for each moment, the distribution of the different categories, showing which activities were more common during which hours of the day.

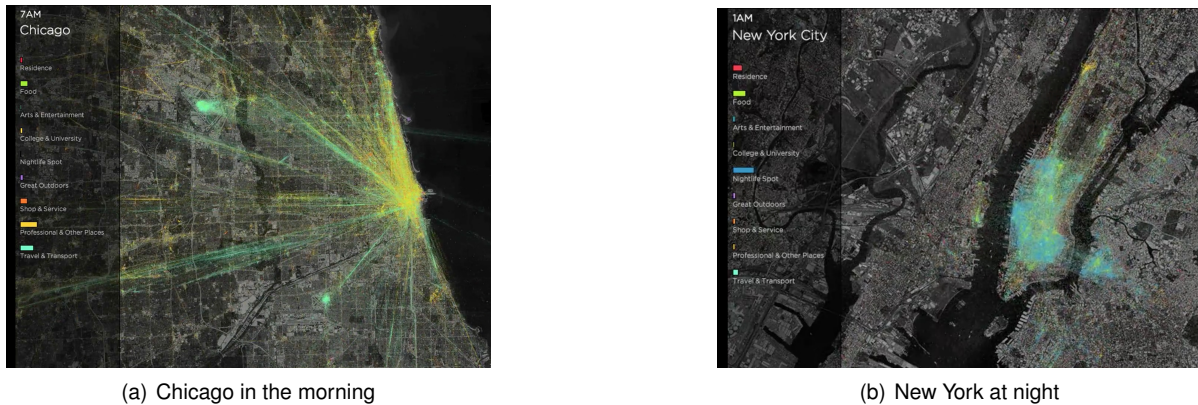


Figure 2.14: Resulting maps by mapping check-ins sequences.

Results consist of different videos⁷ representing a city's pulse; snapshots of some of these can be seen in Figure 2.14. Note the traveling category in Chicago by 7AM, bluish-green dots on Figure 2.14(a), something expected from the commute to work; business and work check-ins are also beginning to appear, unsurprisingly for that time of the day.

The project essentially reveals an automatic method to identify people's general perception of a city. Even though it wasn't the authors goal, the results show how different city areas are used for different activities, possibly making those areas implicitly defined on a person's mind, affecting their perception about a city.

2.3.4 My Globe: Navigation Service with Cognitive Maps

"MyGlobe" [Imbe et al., 2010] is a service developed to offer its users a new city understanding, making use of their cognitive maps, like the emphasizing of frequently used landmarks, paths, and districts.

The service includes custom hardware to explore cognitive maps, using the globe metaphor to emphasize the notion of a "different world" per person. Users can also exchange their maps with friends to uncover different places and areas, this results in yet more ways to look back into their own city and gain a new understanding.

MyGlobe is divided into three different services. A mobile application, an online engine, and a custom-made device.

The app has the main function of location logging, sending to online servers the precise GPS location every fixed seconds; it also supports other actions such as viewing cognitive maps for the current location, sharing maps with friends, and tagging. It is then possible for users to use friends' maps, or even strangers' maps for the current location, as guides to further explore the city, seeing their known

⁷Last visited on 30.10.2014 at <http://vimeo.com/foursquarehq/videos>

territory as islands and their favorite places highlighted as large icons on the map, as shown on Figure 2.15(b).

The online engine, residing on the service's servers, represents the most complex part of the project. It receives, as input, each logged location, processes it, and then combines the different locations into islands, and highlights frequented roads and buildings. Island is the chosen metaphor to represent the user's known areas, each one surrounded by water (unknown/unfrequented territory) and having the possibility to expand; these are estimated using an algorithm that locates the center of a group of logged locations, chosen based on the proximity among them. The system also represents highly frequented roads and streets as paths, the more the user uses such paths the more they widen on the cognitive map. The same goes with frequented buildings, titled as landmarks, as the respective icons on the map are sized according to the time passed inside of them and the number of times the user enters it.



Figure 2.15: Different components of the MyGlobe service.

Finally, the device chosen to represent and explore the user's cognitive map is based on a globe, Figure 2.15(a); the navigation is done using rotation exactly as usually done in such an object. This choice is to emphasize the fact that the world, for each person, is simply the places that the same person attends and visits.

This work is developed around the assumption that each person has her perception of the world, and that it is mainly shaped by daily quotidian habits. The results support this assumption by showing how different people build different maps, shaped by their habits. Although there is not much data around the achieved results and consequent thought around them, this project lays down a path for ways to build and observe a person's cognitive map.

2.3.5 The Livehoods Project

When outsiders, such as researchers, journalists, or city planners, want to know more about a city, they usually spend a lot of their time observing static data and interviewing the city's inhabitants, just to understand city's living dynamics. To solve such problem, "The Livehoods Project : Utilising Social Media to Understand the Dynamics of a City" [Cranshaw et al., 2012] develops a new methodology for studying, on a large and general scale, the dynamics, structures, and a character of a city, giving those

prior personalities a starting advantage over this issue. It is composed by three different parts, or steps: a clustering model for discovering the distinct geographic areas of the city; a series of semi-structured interviews with city residents for exploring the resulting clusters and the urban dynamics that shape them; and an interactive web-based tool for visualizing those clusters, allowing the discovery of new insights about the city. The paper reveals the results of this work's application in the city of Pittsburgh.

The clustering model is based on well-known algorithms of spectral clustering. Millions of Foursquare check-ins (totaling 18 million) were provided as input to the model. For each check-in, the accounted data consisted of user ID, time of the check-in, the geographic coordinates, and the name and category of the venue. The main algorithm took that data and grouped venues according to their spatial and social proximity, the latest increasing with the amount of users in common who checked-in among those venues. The result comes as mapped geographic areas of the city, representing clusters of venues related between them; to such clusters, the authors call Livehoods, reflecting the definition of a neighborhood based on the living dynamics of a region.

To validate the resulting areas, 27 residents were submitted to semi-structured interviews. These began with questions about each participant's background and his neighborhood. Then, without specific instructions, they were shown a map of Pittsburgh and asked to draw the boundaries of their neighborhood over it - this permitted right away the observation of differences across official municipal neighborhoods, the generated Livehoods, and those drawn by the analyzed residents. On the same resulting map, they indicated if there was a specific place where they felt a "shift in feel" of the neighborhood. Finally it was presented an interactive map which showed the official municipal boundaries for each neighborhood and it was asked for the respondents to give their opinion if there were any shifting borders. The resulting Livehoods map was also presented and feedback was gathered, resulting in an overall positive opinion.

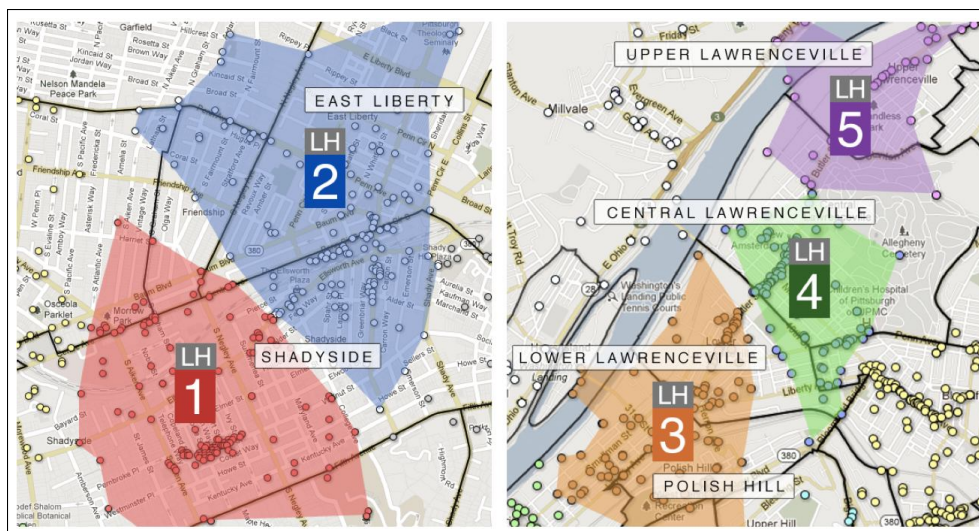


Figure 2.16: Resulting maps after the Livehoods clustering process.

Among the results, we show a particular case where the identified Livehoods were very different from the formally established neighborhoods, Figure 2.16. Here we can see, comparing the colorful areas with the black lines, that Livehoods LH1 and LH2 represent different cases. LH1, in general, is contained inside the Shadyside boundaries, while the LH2 spills into the east of the previous and to the north of

its boundaries. This fact was later confirmed by the questionnaires, as explained by the respondents: Shadyside, seen as a wealthy area of the city, has its main social center around Walnut Street (see the density of highlighted venues on the south of LH1, Figure 2.16) and it is frequented mainly by older and richer people; East Liberty, a poorer area, has developed to the point of seamlessly unite with two of Shadyside's business districts, and nowadays all of that area is being frequented by young population. This shows that demographics play a very important role on how a person experiences the city and on what venues she chooses to visit.

From the construction of these maps, we can retrieve that people develop certain patterns regarding the places they visit. These patterns are completely independent from the neighborhoods imposed by municipalities and instead seem influenced by age and socio-economic conditions of the population of a certain area. Also, since the inquired residents identified the generality of the livelihoods, it's clear how the perception of the city can be related to the social habits within certain areas, showing how this method could help us in the comparison of a person's mental map with the place they live.

2.3.6 Live Cities

It's difficult, even for a resident, to characterize a city's social dynamics, and to reveal to foreigners the ever-evolving activity patterns inside it. Addressing this problem, the authors present an improvement over city areas classification using semantics from venues and from the online profiles of people who frequent those places [Del Bimbo et al., 2014]. This classification is based on the clustering of data from location based social networks, combined with techniques of user profiling. A web app, LiveCities, was used to show those different clusters as the "hidden character of the city".

The process was applied to several Italian cities, the one with more detailed results being Florence. The data that fed this project was collected from Facebook profiles, where users' posts are iterated, and looked up for associated locations. The retrieved locations are then put through Foursquare's API to find their category. Finally, for profiling, users' interests were found by looking up the category of their "liked" Facebook pages. This assures that each venue is characterized by both static (Foursquare category) and dynamic features (distribution of the interests of the people who checked-in to the venue).

The clustering module took into account similar distances between venues, where three different methods for evaluating those distances were used: geographic proximity, using latitude and longitude; Foursquare based proximity, which adds category info; and finally, a socially aware method that, in addition to the Foursquare based process, takes into account the interests of the users that checked-in to the venue. The authors' focus is in this last method, which reflects the goal to exploit people semantics and semantic distances to better refine places categorization. Essentially, it tries to understand the type of people frequenting a venue by analyzing their interests' categories, then, it finds the semantic similarity between those categories and the one extracted from Foursquare. In the end a new classification is made, characterizing the ambient of the venue based on what kind of people visit it, linking venues with similar social dynamics and, eventually, creating a cluster for a city area.

After collecting and treating all the data, the developed web app provides two different views on the

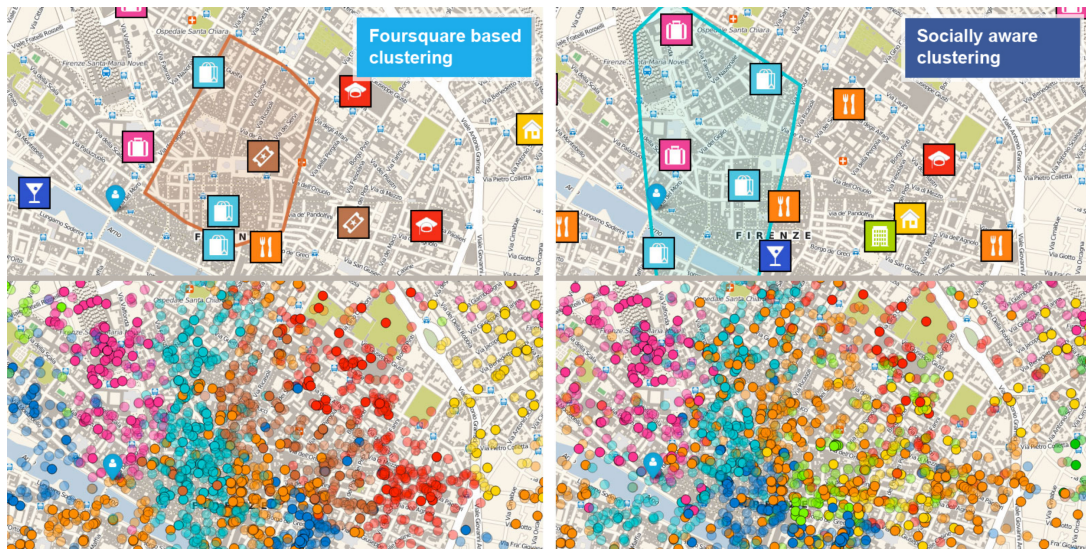


Figure 2.17: Resulting maps after two different venue clustering modes.

results. The first is a normal maps view, which provides easy search of attractions and other places, optimized accordingly to the done work. The second is focused on showing the resulting clusters, being possible to choose the type of clusters to see based on the geographically, Foursquare, or socially aware methods. In Figure 2.17, we can partially see the results for the city of Florence, and the difference between a Foursquare-based, left, and the socially aware clustering, on the right.

These results were tested against a questionnaire to 28 people. It consisted of showing a map of the city divided into 15 numbered cells; for each of those cells, participants were asked to label them by assigning three different categories, according to their mental map. Since each cell could contain several clusters, the authors focused on how that labeling aligned with the detected clusters, and measured the displacement in the weights of its venues categories. The data showed a good correlation between what users identified and what was found by the socially aware clustering approach, validating the project.

This work reveals how a subjective mental map can be related to gathered objective data. Areas of the city can be associated with certain activities and interests, also revealing the kind of people who frequent them; it is a pattern that not only shows itself in the city environment, but is also picked up by the population, affecting their perception of the place. This approach also shows how simple exploration of people semantics, such as their interests, can be critical to understand the social dynamics of the analyzed space, and how revealing it can be about a person's mindset.

2.4 Discussion

The previously presented projects all contemplate important research and findings in the fields most related to ours, helping us to find the best solution to our problem.

We tackled studies that looked into people's space psychology, trying to find influences and determinant factors in one's space perception. Those studies not only helped us understand how people naturally understand space, but they also showed how we should interpret results from a mental maps

	Data Type	Gathering Method	Analysis / Compilation Method	Data Analyzed	Generalized Mental Map	Explored Background
2.1.1 Immigrant Children	Subjective	Manual	Manual	Sketched Maps, Interviews	No	Yes
2.1.2 S. Francisco M. Maps	Subjective	Manual	Manual	Sketched Maps, Interviews	No	Yes
2.1.3 Place Brand	Subjective	Manual, Digital	Manual, Digital	Opinion on areas	Part.	Part.
2.1.4 Paris M. Maps	Subjective	Manual	Manual	Sketched Maps, Interviews	Part.	Yes
2.1.5 Suburbs M. Maps	Subjective	Manual	Manual	Sketched Maps, Interviews	No	Yes
2.2.1 Boston Boundaries	Subjective	Digital	Digital	Drawn Borders	Yes	No
2.2.2 M. Maps of the Coast	Subjective	Manual	Digital	Drawn Borders	Yes	Part.
2.2.3 Streets of London	Subjective	Digital	Digital	Place Recognizability	Yes	Yes
2.2.4 Drawing Chicago	Subjective	Manual	Manual	Sketched Maps, Opinion on areas	No	Yes
2.3.1 Tweets Lang.	Objective	Digital	Digital	Social Networks Patterns	No	No
2.3.2 Tourist vs Locals	Objective	Digital	Digital	Social Networks Patterns	No	Part.
2.3.3 Cities Pulse	Objective	Digital	Digital	Social Networks Patterns	No	No
2.3.4 MyGlobe	Objective	Digital	Digital	Location Habits	No	No
2.3.5 Livehoods	Objective	Digital	Digital	Social Networks Patterns	Yes	No
2.3.6 Livecities	Objective	Digital	Digital	Social Networks Patterns	Yes	No

Table 2.1: Summary of each project's approach, referenced by their respective section number. "Manual" is used to describe face-to-face, human-executed, or just analogical processes. "Part." stands for "partially", attributed to something that did not entirely fulfill the attribute.

study, and thus, how to gather data in such a manner that we can end with meaningful results.

Closely related to those studies, are the projects that described ways to gather a group's subjective image of space. We took care in both covering the projects that applied interesting methods of collection, and those that just showed us good ways to analyze highly subjective data.

Furthermore, we also gathered a series of projects that cared more about trying to find patterns in the general spatial behavior of a population, in order to discover how they perceive space and create imaginary boundaries.

Table 2.1 shows a summary of the approach of each of the analyzed projects. There, we qualify each work in the type of data used, the method used to gather that same data, and the method used to process and analyze the results in the end. We also specify the main source of data, and whether they were able to produce a general, or "average" mental map. Finally, we specify if any background information of the analyzed population was gathered.

As we first look to the table, we see that no project that used the sketching method used a digital, automated tool to either gather or analyze the data. This points for the usefulness of, and need for those tools.

Then, we notice that most of the works that involved a digital method for data gathering, processing, and analysis, concentrate around pattern finding (in other words, most digital tools are under the "Data Driven Approaches" group). One more time, this shows the lack of digital, or computer-executed processes, as most of the existing were developed under this pattern finding paradigm.

Finally, it shows how works from Section 2.2 are divided among themselves as what is the best way to find mental maps, as four different works resort to three completely different types of data.

Gathering these insights together, it is obvious there is a need for an effective and efficient way to find a mental map of a population. The consensus seems to lie in the sketching method as the best way to observe mental maps, however, and as we've analyzed throughout this chapter, conclusions are hard to come by when gathering those results. On the other hand, projects that solve that last problem are faced with others, as proven by the lack of consensus around the best way to build a mental map when

resorting to some other data than sketches.

Considering all of the different projects we've looked into, we were able to find what we consider to be the **best, easiest, and quickest way to find a population's mental map**, compromising some accuracy of the sketching method, but giving in return an alternative that's both effective and efficient enough to be taken as the default approach in these kind of studies.

As mentioned in Chapter 1, we intend to build a framework that both allows the gathering and analysis of data. It should cover each one of the attributes on Table 2.1 with what we consider to be the most appropriate values. As such, we focus on **gathering subjective data**, for the power it can have if well analyzed. At the same time, we stick to **digital methods for both gathering data and analyzing the results**, for the possible efficiency it can bring to any study. We also want to make sure it is possible to **produce some image or map representing the generalized mental map of a population**. The other three attributes were open to more discussion and deliberation, but the previous set of decisions helped in restringing our options.

We must **be sure to support the exploration of background information**, as most analyzed works have shown just how decisive its inclusion, or not, can be. But not only should we allow for simple information such as age and gender to be retrieved, there must be a way to **retrieve spatial information on the habits of the participant**. With this, a researcher would be able to harness the power of most works from Section 2.3, but as a way to better explore the gathered subjective data.

Regarding the source of the subjective data, while digital tools don't allow for a fluid experience in regards to drawings, even if we decided to include free sketching of maps, the later analysis wouldn't be able to add much to the non-digital approach, as quantitative comparisons would still be impossible. Both interviews and openly given opinions were also eliminated as options, considering the similar difficulties in accounting and quantifying them when analyzing the results. As for "Social Media Patterns" or derivatives, we eliminated them based on the fact that such kind of data is inherently objective, not fitting into our initial requirements.

We thus decided to promote the **drawing of borders as the main source of subjective data**, believing in its power when coupled with information on the participants, like comparing results by subgroups of people.

As we decided on what our framework should offer, we came up with an exact list of requirements, presented in the next section.

2.5 List of Requirements

Here we list the requirements for two important things concerning our work. First, we address the interactions a mental maps survey should include for it to be effective. Second, the requirements to have a usable framework and to properly provide its value to other researchers.

As such, and based on the conclusions taken throughout this chapter and especially on Section 2.4, the requirements to create an effective mental maps survey are:

- **A questionnaire** - This should be a mandatory step on a survey and should cover all relevant

background information than can be retrieved by simple questions with quantifiable answers, such as numbers, options chosen on multiple-choice questions, and dates.

- **Spatial Habits and Important Places** - There should be a step where participants could point on a map places important in their day-to-day living, in order to better absorb participants spatial behavior. Well made, this objective and exact information can backup many subjective data given under drawn boundaries.
- **Drawing Boundaries** - For effectiveness, a survey must include at least one step where participants are asked to draw what they think to be the boundaries of some target area. Through this data, respondents are showing what space they associate with a name, and thus exposing their mental map.

We believe that by creating a survey that includes at least one step of each of these three interactions, researchers should be able to observe a population's mental map, while also being able to identify subgroups of interest, through the selection of participants by their spatial or background information.

The requirements for our framework take these previous into consideration, as the features it includes try to implement them.

- **A flexible system for creating surveys** - As we want to accommodate every possible study on mental maps, we should offer researchers the most flexibility possible in what regards the design of a survey for their study. Thus, it is important to guarantee the development of a system that allows the specification of a survey, offering the possibility to include any number of each of the several interactions the framework supports.
- **A survey interface** - The framework should also be able to read the survey specification, and generate the interface according to what's specified. It should prioritize usability in order to reduce the number of quitters.
- **An easy to access survey** - The framework should allow easy deployment of the survey on an website, eliminating barriers of space between researchers and respondents, and increasing the possible number of participations.
- **Questionnaire in survey** - The framework should allow the inclusion of at least one questionnaire inside the created survey. This should offer the proper tools to help researchers cover most background information they might be interested in getting.
- **"Point on a map" in survey** - It should be possible to include on our surveys an interaction where respondents can point places in a map, thus describing their day-to-day living and habits in a spatial context, but with objective and quantifiable data.
- **"Draw boundaries" in a survey** - As the main source of subjective data, and the main contribution for the observation of mental maps, our framework must guarantee the possibility to include this interaction on a survey. It should allow the user to freely draw, on a top of a map, what he thinks to be the boundaries of some specified area.

- **An analysis interface** - In addition to a survey interface, our framework should also provide an analysis interface, made for the researcher. It should adapt itself for the survey it is analyzing and focus on free and flexible exploration of the results.
- **Filtering results when analyzing** - In order to guarantee the exploration of subgroups of mental maps, the analysis interface should include a way to filter results based on the values given by participants on selected interactions. E.g. select only respondents that pointed Bronx, N.Y.C, as their place of living.
- **Explore correlations when analyzing** - It should be possible for researchers to explore and export quantifiable data, allowing for further analysis of correlations on separate tools.
- **Save results** - The analysis interface should offer a way to save the results, either as already processed and compiled data, or as raw data.

This list of requirements is what guided us in designing our framework, to which we've called Semantic Cities framework. Next, we address how we planned and implemented it.

Chapter 3

Semantic Cities

This section contains every relevant detail about the Semantic Cities framework's implementation. It highlights our choices in technology, the design decisions taken along the way, and the trade-offs we had to make.

As already mentioned, the idea behind our framework is to facilitate the deployment and later analysis of a mental maps survey. As seen in Section 2.5, this implies the creation of at least two different applications: one to gather data for the survey, where participants would answer questions and give their personal opinions; another to analyze the data gathered by the survey, where the researcher would explore the participations and make up his/her conclusions.

As one of the priorities was to reach the greatest number of people possible, we decided to make a **web-app for the survey interface**, which in turn made us decide to also **implement the other tool as a web-app**, facilitating compatibility, implementation, and coherence. Furthermore, to keep the framework as simple as possible, we took on the challenge to have **no dedicated server continuously running behind the two applications, thus processing everything on the client side**. Hence, the requirements to use our framework are only a host server, a domain name, and a database. This greatly facilitates the deployment, and lowers the associated costs of our tools.

The resulting implementation of our framework, as expected, follows the path that was laid down by the requirements listed in Section 2.5. Beyond the already mentioned two-part framework, the list also implied, in order to both preserve the targeted flexibility and implement all the different interactions, the creation of a survey system that works on a step-basis. As such, a **Semantic Cities survey is characterized by being composed by a series of steps, or phases, where each of them implements one of the following interactions:**

- **“Survey Information”** for simple briefing or debriefing steps, where the only interaction is to provide information to the participant;
- **“Questionnaire”** for a phase with questions to answer directly, similar to common online forms;
- **“Point a Place”** for a phase where participants are asked to point to one single place on the map, by dropping a marker on that position;

- **“Point Multiple Places”** for a phase where participants are asked to point to one or more places on the map, by dropping a marker on each of those positions;
- **“Draw Area”** for a phase where participants are asked to draw boundaries of a specific area, as a polygon on top of the map;
- **“Draw Multiple Areas”** for a phase where participants can choose to draw the boundaries of one or more areas among a list of them.

These interactions are the closest implementation of what is generally described in Section 2.5, considering the different trade-offs that the technology made us make.

With such structure, the first problem to address was how we could make the two parts communicate correctly. Not only the data gathering tool should know how the survey is designed, but also the analysis tool should know all of the available questions, in order to allow the selection and manipulation of the answers' data. Furthermore, regarding the data used by each of the applications, the first should save the participations, while the second should load their data.

To accommodate both these requirements there must be, first of all, a common language between the two parts, and for that effect we created a **specification in JSON that describes a survey**. It consists of an array of objects, where each of them represents a page of the survey, or what we call a survey phase. That same JSON array is shared between those two applications, and each uses it for its own purposes.

In addition to a survey specification, there must be a common specification for saved participations, since one app will be writing them, and another will be reading them. For this, **another JSON specification was created, representing each participant's input as an array of objects, and where each object will differ according to type of phase it originates from**, as detailed further down in Section 3.3.

JSON was chosen right from the start mainly because of its flexibility, and its compatibility with Geo-JSON, an object notation used to represent geometrical and geographical shapes, and thus something deeply related with our project, as later detailed.

Having defined *what* will be used to allow the communication between the framework's two interfaces, we had to decide *how* that would happen. Since analyzable data will always come from one web-app, and only read, without modifications, by the other, we settled for a very simple database system.

We chose MySQL¹ as the database language, based on its wide use and support, along with the fact that it was one of the few compatible systems with our college's databases. And while there are generally better options to save JSON objects, for the sake of simplicity for both us and future users, we preferred to choose one of the most widely available options on the market.

As we noticed that both web-apps would reach a high level of complexity, combining a complex interface with many different elements and interactions with extensive functionality, we decided to use AngularJS (version 1.4)², in order to facilitate the implementation. It is a JavaScript framework that helps

¹<http://www.mysql.com/> last visited on 06.10.2016

²<https://angularjs.org/> last visited on 06.10.2016

separate data visualization from the logic behind it. While there are several JavaScript frameworks that address this problem, at the time we started the project AngularJS was the most referenced on online tutorials and examples, and maintained an avid supporting community, both critical points for us. Besides, it included direct support to import JSON objects, and indirect (but simple) support to export data to MySQL databases, just as needed.

As AngularJS could not directly make MySQL calls to the database, we made use of pre-written PHP scripts, something directly supported in that framework. This way, the AngularJS application must only call the PHP script and the later would make the due calls to the database, later explained in Section 3.2.

Regarding the interface, and to maintain a coherent style across the framework, we also made use of Bootstrap CSS³ for general styles rules, and Font Awesome icons⁴ for the icons used throughout the apps.

One of the core functionality of our framework, for its both sides, is the interaction with maps. The basic manipulation, such as tile projection and panning, is handled by a mature JavaScript library, Leaflet.js⁵, chosen for its open source, wide use, and its high number of plugins that further extend its functionality. For the different needed interactions with the map we ended up using Leaflet.FreeDraw⁶, Proj4Leaflet⁷, Leaflet-Image⁸, and Turf.js⁹. Their uses will be later detailed.

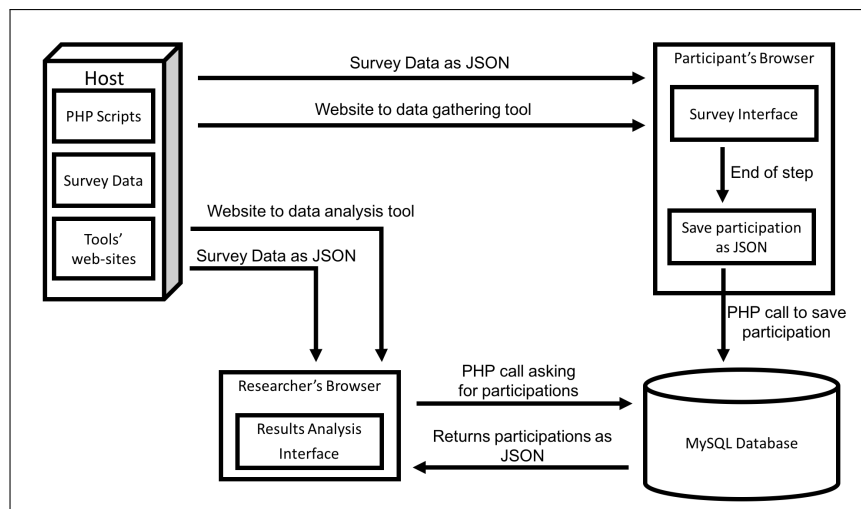


Figure 3.1: Solution schema

Figure 3.1 depicts an overview of our planned solution. It composed, firstly, by a host that keeps the two applications accessible as normal websites, while also keeping complementary data such as the JSON file describing the survey, and the PHP scripts for interacting with the database.

Then, at the participants' browser the "data gathering application" is loaded from that same host, later making the request for the survey's JSON, and finally rendering the survey as specified by that file.

³<http://getbootstrap.com/> last visited on 06.10.2016

⁴<http://fontawesome.io/> last visited on 06.10.2016

⁵<http://leafletjs.com> last visited on 06.10.2016

⁶<https://github.com/Wildhoney/Leaflet.FreeDraw> last visited on 06.10.2016

⁷<http://kartena.github.io/Proj4Leaflet/> last visited on 06.10.2016

⁸<https://github.com/mapbox/leaflet-image> last visited on 06.10.2016

⁹<http://turfjs.org> last visited on 06.10.2016

As participants progress through the survey, the program's code keeps updating the saved participation in the MySQL database, calling the PHP scripts for that effect.

Finally, at the researchers' browser, a similar loading process occurs, as the web-app and then the survey data are loaded into the browser. One single PHP call is made right at the start, requesting every non-empty entry on the database. This data from the participations is loaded into the browser, and instantly available to the app, which code is now responsible for relational operations and filtering.

Bellow we explore the nuances of each of these main parts. We begin with the host and database, as we delve into their technical specifications and behavior. Next, we look into the JSON specifications we use to describe a survey and to save the results. Finally, we talk about the interface and functionality of each web-app, focusing on the general visual language and main algorithms and behavior.

3.1 The Host Server

As previously mentioned, both parts of the framework will run on the client side. This means that there is no dedicated server handling requests for data or functionality from a web-app. Instead, all of the logic and functionality resides in the clients' browser, as its written directly into each tool's code.

This leaves the server with a much simpler job, one of a simple web-site host. It is only required to answer requests for files, and thus it doesn't need any kind of constantly running script, such as a NodeJS application.

A Semantic Cities host is thus only responsible for storing and providing all the necessary files of both web-apps. These include the HTML, CSS, and JavaScript files for each website. In addition to those crucial files, it should keep the JSON specification of the designed survey, and the needed PHP files for interacting with the database.

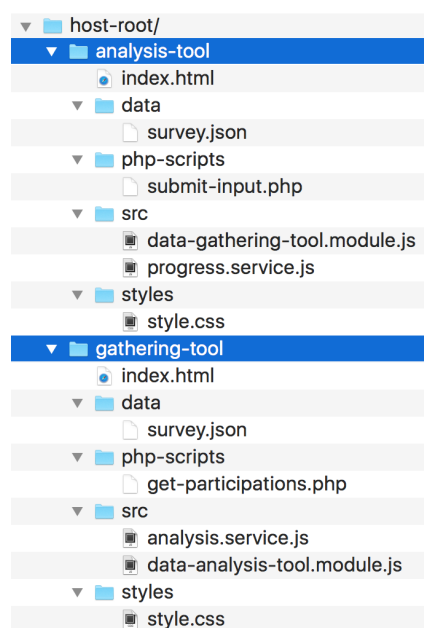


Figure 3.2: Possible directory structure of a Semantic Cities host

In Figure 3.2 we can see a **possible, but not mandatory** directory structure for a fully deployed Semantic Cities framework. To guarantee flexibility on its deployment, we designed each application's code to allow easy configuration of the paths to the different files. This supports situations such as when the framework is deployed on some other directory than the host's root.

Note, also, that as researchers deploy the framework, they **do not need to worry about the details of the directory structure**, as each web-app is already duly organized into folders. Instead, they should only guarantee that **each program resides in separate directories**.

In addition to those responsibilities, researchers must also **upload their survey specification** to any desired directory, inside or outside the apps' directories. Of course, as they decide where the survey data will reside, they should **configure the previously mentioned directory paths inside both programs** to duly point to the resources.

3.2 The Database

The database follows the simplest possible approach. As we planned it, we found that a simple table would suffice to support the storage of all participations.

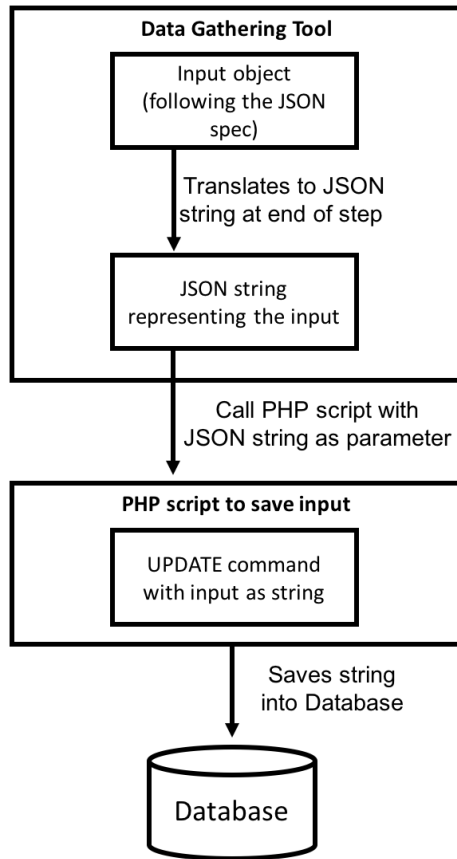
For each saved participation, the database has a single row, containing only two columns, one for a number identifying the participation, and another where the JSON produced as the input is stored as a large string of text.

We settled for a `MEDIUM_TEXT` type of column for storing the participations, each cell supporting 16 MiB of text. This corresponds, for most cases, to more than 15 million UTF-8 characters, and thus certainly enough to store any real world participation as a JSON string.

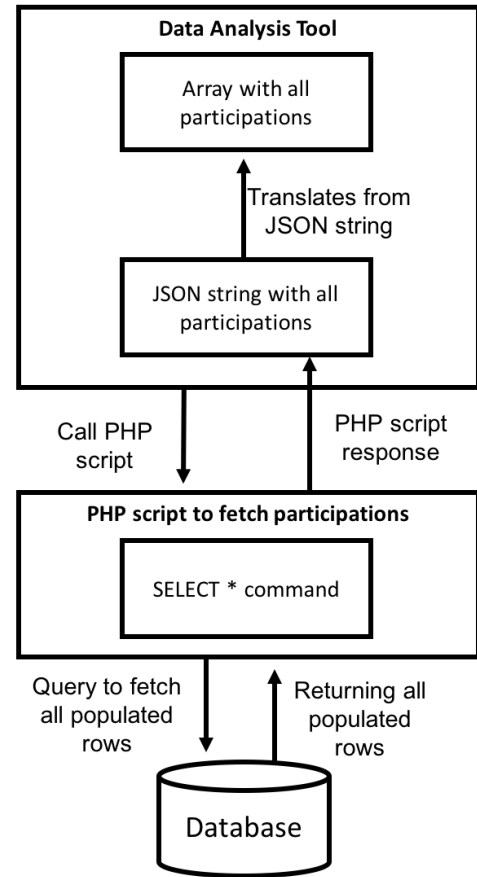
Concerning communication with the database, and as previously stated, all request are made through PHP scripts. These scripts are pre-written as the web-apps requests are always the same and only differ in arguments.

To submit data to the database, and store it, the data gathering tool must execute the process described in Figure 3.3(a). At the end of each step, the program translates the accumulated input from an object to a JSON string. The program then calls the due PHP script, requesting it through its address on the host server, and passing the input JSON string as a parameter. As the PHP script executes, a `UPDATE` command is made to the database, thus storing the participation. Note that the use of the `UPDATE` command is only possible because an entry on the database is created right at the loading of the application, through a `INSERT` command. It follows a similar process, but instead uses another PHP script to create one row on the database, and get the generated participation ID – the first column on each row of the table.

The download of participations into the Data Analysis Tool, schematized in Figure 3.3(b), is similar to their submission to the database. Here, however, there are no arguments passed from the program into the PHP script. Instead, the program waits for the return of the PHP script. Its return value originates from a `SELECT` command over all the non-empty rows on the database, asking for the "participation" value of each of those rows. Those values are then put together into one single array, resulting in an



(a) Schema of the input submission process, from the survey tool to the database



(b) Schema of the process of fetching participation data, from the analysis tool to the database and back

Figure 3.3: The different database calls, and the processes behind them.

array of JSON strings. Finally, the PHP script turns that array itself into a string, returning it as JSON compatible array.

3.3 Data Objects

As previously stated, the specification of a data object was critical to the framework. We needed to be able to both generate a survey, and analyze it solely based on a simple JSON specification. Therefore, this specification must accommodate the wide variability of content a mental maps survey could have (see Section 2.5).

Earlier in this section we introduced the idea of a Semantic Cities survey as a group of phases, each with its own type of interaction. Thus, each phase should be treated as a separate entity, independent from the others. As participants go through each phase of the survey, they contribute with their answers and opinions, generating analyzable data.

Joining this model together with the need of a JSON specification for the survey, we arrived at two different conclusions. One, that a survey can be described as an array with one object per phase. Two, that each phase object, on that array, must have a property, `type`, that is used to describe the different

interactions there present.

We identified six different interactions, specified at the beginning of this section, and thus created six different types of phases, each with its own `type` value. These are: `survey-information`, `questionnaire`, `point-a-place`, `point-multiple-places`, `draw-area`, and `draw-multiple-areas`.

Every survey phase necessarily has the `type` property in common in their JSON specification, see 3.4(a), but each type of phase has their own specific properties, that we address further down.

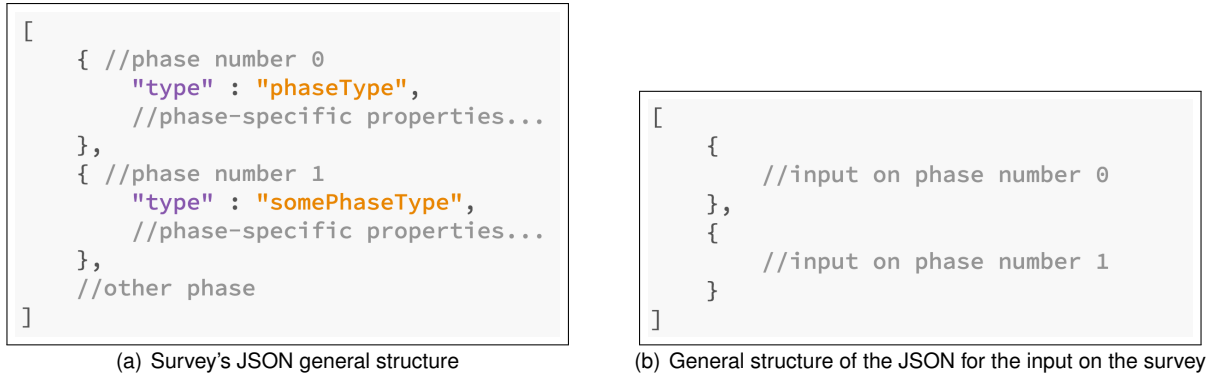


Figure 3.4: General structures for both data objects.

In addition to `type`, there's one more property, `summary`, that designers can include in the specification of every phase. It summarizes what each phase does, and is only useful for the later analysis, helping researchers to easily identify each phase. It's an optional attribute, but recommended for any survey that reaches a minimal level of complexity or big number of phases.

As previously mentioned, in addition to a JSON specification for describing a survey, we also needed to create a standardized JSON representing a participant's input on the survey. For this, we followed a similar approach as we did for the survey specification, breaking it into one object per phase, each representing the input on the phase with same index on the array, as you can see when comparing Figure 3.4(a) with 3.4(b).

We decided to maintain a simple structure on the input object specification, opting for leaving out information of the phase that originated it, such as dropping the `type` property. Instead, we bind the input on each phase to the originating phase by making sure they share the same index on each of the arrays. This implies that the JSON for the input can't be analyzed without access to the survey JSON, as the first depends on the second for its content to have any meaning. We will analyze this later, as we delve into the specification for each phase type, and the input it originates.

3.3.1 Phases of type “survey-information”

Phases of type `survey-information` are simple briefing or debriefing steps in the survey. As so, one of the only needs of its corresponding specification object is a property for the title and the body, specified respectively by properties `title` and `description`. In Figure 3.5 there are two examples of possible `survey-information` phases.

The first, Figure 3.5(a), tries to illustrate a welcome page where basic information about the survey is given, such as its purpose and expected duration. There, in addition to the `title` and `description`

```
{
  "type" : "survey-information",
  "title" : "Welcome to the survey!",
  "description" : [
    "This a survey on dogs.",
    "It lasts for about 15 minutes.",
    "Here's one more paragraph!"
  ],
  "nextSteps" : [1, 2, 3]
}
```

(a) Specification of a “survey-information” phase. Example for a briefing step.

```
{
  "type" : "survey-information",
  "title" : "Goodbye!",
  "description" : [
    "Keep up with the results..."
  ],
  "followup" : {
    "email" : "Provide your email"
  }
}
```

(b) Specification of a “survey-information” phase. Example for a debriefing step, with a follow-up option.

Figure 3.5: Specification of a “survey-information” phase.

properties, it’s introduced one more crucial attribute, `nextSteps`. It specifies an array of phases numbers – indexes on the survey array – to be added to a queue of next phases. We found the need for this as we observed there was no better way, following our planned architecture, to initialize the phases one participant would have to go through. We thus made it a **requirement to begin a Semantic Cities survey with a “survey-information” phase**, where a “next-steps” array must be specified in that same object.

This decision, although limiting, didn’t seem to be a big trade-off, since beginning a survey with a welcome-page should accommodate most designs.

The second example, Figure 3.5(b), illustrates a debriefing step, or the last step of a survey, and it introduces the `followup`. It was created to offer a way for participants to be notified of the survey progress, like sending them a link for a blog post with the results. Currently, the only supported channel is e-mail, specified as shown in the figure. It provides the participants the option of giving their e-mail so the researchers get back to them, if they want to. The value of the property on the object represent an introductory text to, for example, justify the possible gain for the participant on providing an e-mail.

For details on the specification object, and on the input object produced, please resort to Appendix A.

3.3.2 Phases of type “questionnaire”

Phases of `questionnaire` type are among the most complex to specify, for the arbitrary number of questions the designer can include in them. In order to support this feature of having any number of questions in each questionnaire phase, the JSON for a `questionnaire` type of phase must necessarily contain a `questions` property. It is described by an array, and each element is an object representing a question, see Figure 3.6(a).

The specification of the input object produced when interacting with a `questionnaire` phase is similar, but instead of a `questions` array, it has a `answers` property. It consists of an array, where each of its elements is an object representing an answer to a question, and follows a structure specific to each type of answer a question can have.

The specification for each question follows a common structure, starting with the `questionBody` property, the question to ask, and an `answer` object, containing the properties of the answer to give.


```
{
  "type" : "questionnaire",
  "questions" : [
    {
      //question specification
    },
    {
      //other question specification
    }
  ]
}
```

(a) “questionnaire” phase’s top-level specification

```
{
  "questionBody" : "How old are you?",
  "answer" : {
    "typeOfAnswer" : "number-input",
    //...
  }
}
```

(b) “questionnaire” phase’s “questions” common specification

Figure 3.6: General specification for “questionnaire” phases.

As the answer to a question can be given under very different forms, we figure it would be better to characterized each one by a `typeOfAnswer` property, see Figure 3.6(b). Answers types range from:

- `number-input` for answering with a number
- `time-input` for answering with a time period, such as “10 years”
- `month-input` for answering with an approximate date, with only month and year, such as “03.1984”
- `choose-multiple` for answering with multiple items (check boxes) among a list of items
- `choose-one` for answering with only one item among a list of items
- `select-dropdown` for answering with a selected item among a dropdown with a list of items

This comes with the implication that all answer types have their own particular properties, as can be consulted in Figure 3.7 and analyzed in detail in Appendix A.

We should note the nonexistence of an answer supporting participant’s written text. This is due to the problem of quantifying and qualifying such input, thus making it almost impossible to analyze. Nonetheless, the offered options fulfill much of the possible gains that one would have with such answers, maybe just requiring a more clever design.

Furthermore, and as expected, since there are different ways of answering, there are different inputs being produced. Those forms can be seen in Figure 3.8, and are detailed in Appendix A.

As a `questionnaire` phase can be specified using any number of these question objects, each with a wide range of ways to answer it, it offers great flexibility and power to the survey designer. Not only that, it also gives researchers plenty possibilities to explore the background of their participants, and thus back up conclusions.

3.3.3 Phases of type “point-a-place” and “point-multiple-places”

Phases of type `point-a-place`, and `point-multiple-places` share the same properties on their JSON specification. Such thing is possible because the actual difference between these two phase types is the kind of interaction they offer to the participant, and that distinction is to be made by the survey tool itself, as it loads the respective interactions to each phase type.

```
{
  "questionBody" : "How old are you?",
  "answer" : {
    "typeOfAnswer" : "number-input",
    "minValue" : 13,
    "maxValue" : 120,
    "supportText" : "years old"
  }
}
```

(a) "Number-input" specification example

```
{
  "questionBody" : "How long do you know this region?",
  "answer" : {
    "typeOfAnswer" : "time-input",
    "minValue" : 1,
    "maxValue" : 200,
    "timeUnits" : ["Years", "Months", "Days"]
  }
}
```

(b) "Time-input" specification example

```
{
  "questionBody" : "When was the last time?",
  "answer" : {
    "typeOfAnswer" : "month-input"
  }
}
```

(c) "Month-input" specification example

```
{
  "questionBody" : "Which countries have you visited?",
  "answer" : {
    "typeOfAnswer" : "choose-multiple",
    "answerOptions" : [
      {"answerBody" : "Canada"},
      {"answerBody" : "Mexico"},
      {"answerBody" : "Others"}
    ]
  }
}
```

(d) "Choose-multiple" specification example

```
{
  "questionBody" : "Choose your region",
  "answer" : {
    "typeOfAnswer" : "choose-one",
    "answerOptions" : [
      {
        "answerBody" : "West side",
        "effect" : [1, 2]
      },
      {
        "answerBody" : "East side",
        "effect" : [3, 4]
      }
    ]
  }
}
```

(e) "Choose-one" specification example

```
{
  "questionBody" : "In which continent do you live in?",
  "answer" : {
    "typeOfAnswer" : "select-dropdown",
    "answerPrompt" : "Choose a continent",
    "selectOptions" : [
      {"optionBody" : "Africa"},
      {"optionBody" : "America"},
      {"optionBody" : "Asia"},
      {"optionBody" : "Europe"},
      {"optionBody" : "Oceania"}
    ]
  }
}
```

(f) "Select-dropdown" specification example

Figure 3.7: Specification of the different answer types.

```
{
  //input on a questionnaire phase
  "answers" : [
    { //`number-input` answer
      "number" : 18
    },
    { //`time-unit` answer
      "number" : 5,
      "timeUnit" : "Years"
    },
    { //`month-input` answer
      "month" : 10,
      "year" : 2016
    }
  ]
}
```

(a) Input produced by answers of type "number-input", "time-input", and "month-input"

```
{
  //input on a questionnaire phase
  "answers" : [
    { //`choose-multiple` answer
      "checks" : {
        0 : false,
        1 : true,
        2 : false
      }
    },
    { //`choose-one` answer
      "index" : 0
    },
    { //`select-dropdown` answer
      "selected" : "America"
    }
  ]
}
```

(b) Input produced by answers of type "choose-multiple", "choose-one", and "select-dropdown"

Figure 3.8: Specification of the input produced by the different types of answers.

In addition to the usual descriptive elements of the phase, there is the addition of a instructions field, see Figure 3.9(a). We decided to include it in all the phases concerning interactions with the map because of the functionality hidden on the map, like what a click on the map does, or what happens

when clicking on a marker.

While we could have left that to the `description` property, it seemed better to isolate them, so they could be specially treated in the interface, and thus get their due relevance.

```
{
  "type" : "point-a-place",
  "title" : "Place one marker",
  "description" : [
    "Show us your favorite bar.",
    "Point it on the map.",
    "Here's one more paragraph..."
  ],
  "instructions" : [
    "No. 1 - Don't try this on mobile",
    "No. 2 - Click on the marker to delete it"
  ],
  "mapView" : {
    //to setup the map
  },
  "markerRadius" : 250,
  "markerDetails" : {
    "color" : "#aa22dd",
    "fillColor" : "#23b",
    "fillOpacity" : 0.75
  }
}
```

(a) Top level specification of a “point-a-place” phase. Identical for “point-multiple-places”.

```
{
  //...
  "mapView" : {
    "view" : {
      "center" : [38.745247, -9.162425],
      "zoomLevel" : 13,
      "bounds" : {
        "northEast" : [38.925922, -9.416042],
        "southWest" : [38.558712, -8.945160]
      }
    },
    "tiles" : {
      "tilesUrl" : "https://mapbox.or.osm.link/",
      "tilesAttributes" : {
        "attribution" : "MIT license",
        "id" : "semantic.cities",
        "accessToken" : "gibberish",
        "maxZoom" : 16,
        "minZoom" : 12
      }
    }
  }
}
```

(b) Specification of the “mapView” property.

Figure 3.9: Specification of a “point-a-place” phase, and detail of a “mapView” object.

There are a few more properties a survey designer can specify for these phases, as Figure 3.9 shows. `markerRadius` and `markerDetails`, serve the purpose of offering special configuration to the markers that users will place on the map. While the second serves purely the goal of customization, the first is based on the fact that, depending on the case, its important to guarantee a certain accuracy, or lack of it, to the places pointed on the map.

Finally, there's also the existence of the `mapView` property. This is an important attribute for all the phases with map interactions, as it details the needed parameters to properly initialize the map. In it, it contains two more objects, `view` and `tiles`. This way, each can be treated separately by the code that uses them, guaranteeing flexibility. The `view` property regards the view over the map, such as where to center it, and how zoomed-in it will be when loaded. `tiles` on the other hand, focuses on the tile layer of the map, or in other words, the looks of the map, such as the inclusion of roads and terrain. A possible `mapView` configuration can be seen on Figure 3.9(b)

Both these phases generate similar input, producing a GeoJson object for a Feature Collection¹⁰ with as many Point geometry features as the markers placed on the map, see example in Figure 3.10.

3.3.4 Phases of type “draw-area”

The specification of a phase of `draw-area` type is identical to the phases with marker placement interactions, described in Section 3.3.3. The only difference relies on the marker configuration that, for these phases, doesn't exist. We then get a similar specification to one such as shown in Figure 3.9(a), but without the last two properties.

¹⁰See FeatureCollection specification on <http://geojson.org/geojson-spec.html#feature-collection-objects> last visited on 07.07.2016

```

{
  "type" : "FeatureCollection",
  "features" : [
    {
      "type" : "Feature",
      "geometry" : {
        "type" : "Point",
        "coordinates" : [
          -9.162425,
          38.745247
        ]
      }
    },
    //... another Point Feature
  ]
}

```

Figure 3.10: Input object generated by a “point-a-place” or “point-multiple-places” phase.

Although the similarities when describing the phase, the generated input is completely different. Since the drawn areas are supported by the Leaflet.FreeDraw library (a decision analyzed in detail later in Section 3.21), the generated input follows that library’s own representation of the free-form polygons that the participant draws on these phases.

```

[
  //polygons
  [
    //polygon 0
    [38.745247, -9.162425],
    [38.925922, -9.416042],
    [38.558712, -8.945160],
    [38.745247, -9.162425]
  ],
  [
    //polygon 1
    //vertices coordinates
  ]
]

```

Figure 3.11: Input object generated by a “draw-area” phase.

Leaflet.FreeDraw saves each generated polygon as an array where each element represents a vertex on that polygon, and where each vertex is described as a bi-dimensional array. An example of the produced array – this phase’s input object – can be seen in Figure 3.11.

3.3.5 Phases of type “draw-multiple-areas”

Phases of type draw-multiple-areas are meant to show, on a single page, a list of neighborhoods or areas that participants can draw on the map. This differs from a group of sequential draw-area phases because, here, the participant can choose only some of the many areas to draw, not going through a much bigger number of phases which areas he doesn’t know how to draw.

Nevertheless, as participants select one of the areas to draw, we figured it made sense to lead them into a draw-area phase for the selected area. As such, the best way we found to do this was to provide, in the draw-multiple-areas specification, a subPhases property. As the name indicates, this attribute is an array where each element represents a draw-area phase to which participants will navigate to, going back to the draw-multiple-areas parent phase when they finish their drawings.

```

{
  "type" : "draw-multiple-areas",
  "title" : "Draw neighborhoods",
  "description" : [
    "We want to find true boundaries.",
    "This is one way to do it..."
  ],
  "instructions" : [
    "Draw as many areas as you like",
    "When ready press 'Next'"
  ],
  "mapView" : {
    //a mapView object
  },
  "subPhases" : [
    {
      "name" : "Bronx",
      "areaNumber" : 0,
      "phaseData" : {
        //a draw-area specification object
      }
    },
    //another area to draw
  ]
}

```

Figure 3.12: Specification of a “draw-multiple-areas” phase.

In Figure 3.12 you can see a possible specification for a draw-multiple-areas phase. Excluding the subPhases property, its specification is identical to a one from a draw-area phase.

The so called sub-phases are described with a name, name property, a unique, but not necessarily sequential number, areaNumber property, and with a draw-area object, phaseData property, just as described in Section 3.3.4. This latter is required to support the loading of the sub-phase as a draw-area phase when selecting the corresponding area for drawing.

As the reader might already figured, specifying all the sub-phase may get exhausting for the survey designer, and is indeed something that points for the use of a “survey creator” tool to bring usability to the creation of phases such as these. However, such feature was left for future improvements, since it wasn’t a critical feature for our framework, as we later explain in Section 3.3.6.

The input produced by a phase of draw-multiple-areas type follows the same idea of the subPhases attribute. It is represented by a collection of draw-area input objects, themselves organized as an object, instead of a more obvious array. The collection object contains one property for each sub-phase the participant visited, as Figure 3.13 shows.

```

{
  "1" : [
    //polygons drawn on subPhase with areaNumber 1
    [
      //polygon 0
    ],
    [
      //polygon 1
    ]
  ],
  "7" : [
    //polygons drawn on subPhase with areaNumber 7
  ]
}

```

Figure 3.13: Specification of the input object produced by a “draw-multiple-areas” phase.

An object representation was chosen over an array for the same reasons that lead us to include the

areaNumber property. This choice assures the correct indexing of areas, a problem we were facing at implementation.

3.3.6 Creating a survey and the “survey creation tool”

We previously briefly mentioned the clear advantage of having some interface that facilitates the creation of a survey data object.

A survey specification can reach high levels of complexity and many things that can be automated, such as numbering and repeating properties, are more prone to human errors for each phase that is added to the survey.

Furthermore, it is difficult to identify errors in the survey specification, as the overall readability is very low. And this also makes it hard for survey designers to review their work.

However, considering that a survey can still be produced without such an interface, we identified this feature as non-critical for the overall functioning of the framework, leaving it for future improvements.

This way, and concluding this section, we underline that the creation of a Semantic Cities survey requires a **creation of a JSON file** that should be populated with an **array with one element for each phase of the survey**, each being duly **described according to their particular specification**. It should **begin with a “survey-information” phase** that itself should specify **a queue of next phases on the “nextPhases” property**, for initialization purposes.

3.4 Data Gathering Tool

As we’ve mentioned before, our framework has two main programs: a data gathering tool, and a data analysis tool. Here we will describe in detail the first of those, and will dive into the overall code structure, the main algorithms, the different elements of its interface, and the decisions we had to take to implement the application.

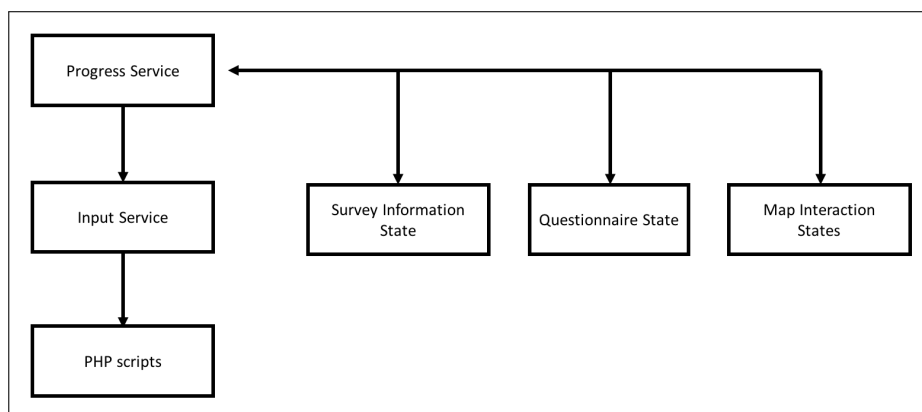


Figure 3.14: Architecture schema for the Data Gathering Tool.

We described in Section 3.3 how a Semantic Cities survey consists of a series of phases, each with its own interaction and configuration. Faced with this situation, we needed to make our code as flexible

as the survey specification, and, consequently, we decided to implement the simple but effective pattern of a state machine. By making use of an external AngularJS library named UI-Router¹¹ we were able to implement such solution easily and ended up with an architecture such as the one shown in Figure 3.14.

There you can see the “Progress Service”, a master entity that communicates with every possible state, and each state with it. This service is responsible for keeping track of where in the survey the participant is and where it should go next. Every time the user advances to the next phase the progress service will load that phase from the survey data and associate it with its respective state.

There’s also the existence of an “Input Service” which is only responsible for communicating with the appropriate PHP scripts in order to submit the user input, isolating that behavior on a separate block of code. This code is called by the progress service **every time the participant loads another phase**, thus saving the accumulated input at the database whenever there’s new, confirmed input.

The code for each state covers its template and functionality, both unique to it. However, each of the states share some similarities between them, in those two fields.

The most relevant common feature, is the necessary existence of a **“progress” button**. Every phase state, regardless of its type, has this button, as it is the only way to allow the progression through the survey (the exception being the last phase of the queue, that automatically hides its button, which would otherwise lead to nowhere). The button’s style it’s standardized thanks to shared CSS rules, and its functionality is also identical among states thanks to the communication with the progress service, which provides a function for the effect.

It’s when that button is pressed that most logic regarding the whole of the web-app code is executed. The progress service, at that moment, **submits the user input** to the input service, **loads the next phase** on the queue by getting its configuration from the survey data object, and **changes the state** according to that phase’s type.

Next we address the specific behavior of each state, and its unique properties, both on the interface, and in its code.

3.4.1 “Survey Information” State

The state for phases of type `survey-information` has both a straightforward interface and simple functionality. Two examples of these phases’ interfaces can be seen in Figure 3.15.

The first example, Figure 3.15(a), illustrates a simple welcome page, where one can see the title highlighted in red, the description in blue, and the previously mentioned “progress button” in green. Notice also, in purple, how we represent each one of the several paragraphs of the description, an idea introduced in Section 3.3.1.

The second example, Figure 3.15(b), shows a possible final phase, with an option for follow up through e-mail, in red. Note that the blue shape surrounds the describing text for this same field, as explained in Section 3.3.1.

¹¹<https://ui-router.github.io/ng1/> last visited on 07.10.2016

Welcome!

Welcome to our survey! You are contributing for a study and master thesis for Instituto Superior Técnico, from the University of Lisbon.

You will help us understand how people perceive the city of Lisbon in terms of space and feel. To do this, you'll have to answer some basic questions about yourself, and show us your perception of the city by drawing on a map.

This should take you about 10 to 15 minutes to complete, but it will be fun!

Note: this survey is not prepared for mobile devices. If you are using one, we advise you to come back when you are on a computer.

Thank you and good luck.

Next

(a) Example interface for a phase of type “survey-information”, a “welcome page”.

Thank you!

You finished the survey. Your answers are saved.

Thank you for your participation!

If you want to know the results of this survey, insert your email below. We will send them to you when possible.

Email: Save

(b) Example interface for a phase of type “survey-information”, a “debriefing page” with “follow up” option.

Figure 3.15: Examples of possible interfaces a “survey information” phase can have, with their different elements highlighted.

Both these cases illustrate the translation of the text elements, such as the title and description, from the JSON specification directly into the interface. Thanks to our architecture, and to the way we separated each field on the specification, we need only to care with how we display the content of each property, and not with what those contents are.

Besides that simple binding between data and interface, this state’s implementation required only attention to the “follow up” element, as we had to submit the inserted e-mail as the input on the phase.

3.4.2 “Questionnaire” State

Just like its JSON specification, the state for a phase of type `questionnaire` was one of the most complex to implement, mainly for its wide possibilities of content.

As introduced in Section 3.3.2, a questionnaire has a variable number of questions, and each question has one of several ways to be answered. Therefore, we had to shape our code to be able to render each question differently, depending on its specification, much like we did with the whole survey and its phases’ types.

Thus, beyond a template for the questionnaire itself, and a common style for each question’s body, we had to create a predefined template for each type of answer. As the application loads each question, it renders the answer field using that template, and fills it accordingly to the configuration given in the JSON specification.

In Figures 3.16 and 3.18, we display possible questionnaire interfaces, covering all types of answers. As you can see right in Figure 3.16, a “question” element consists of the question to be asked, bordered in red, followed by a field for the answer, in blue.

In that particular picture, the answer field shows how a `choose-one` type of answer is displayed, following the convention of representing each option as radial buttons with their labels, and allowing for only one option to be selected.

Note that, by only allowing the selection of one option, the answers to this type of questions can easily distinguish participants, separating them into categories. It was based on that fact that we created

What best describes your situation?

- ☒ I was born in Lisbon and I still live there
- ☐ I was born and lived somewhere else, then I moved to Lisbon
- ☐ I don't live in Lisbon, but I work/study there (daily commuter)
- ☐ I lived in Lisbon
- ☐ I visited Lisbon
- ☐ I never lived in, nor visited, Lisbon

Next

Figure 3.16: Interface for a question with a “choose-one” answer.

the `effect` property on the specification for this kind of answers (see Figure 3.7(e) in Section 3.3.2), allowing survey designers to designate different survey paths depending on what options participants choose. This is a crucial functionality, since it can dictate the overall experience of the survey.

We created a function to be executed whenever an option with an `effect` property is selected. The function simply replaces the previous path by the one specified. We decided to represent that path as a queue (“FIFO”) data structure of phase numbers, pushing out each number and loading the corresponding phase as participant progress through the survey.

It is important to remember that when applying the effect of an option, the queue of phases is not modified, but rather **completely replaced** by the one specified at the `effect` property. Although we recon that is a possible source of errors, we opted for this behavior to simplify the implementation and mitigate problems on the programming side of the app. Thus, the survey designer must be cautious when using this feature, opting to apply an effect that specifies the next steps only until another path-changing phase appears, leaving that new responsibility to it alone, as illustrated in Figure 3.17.

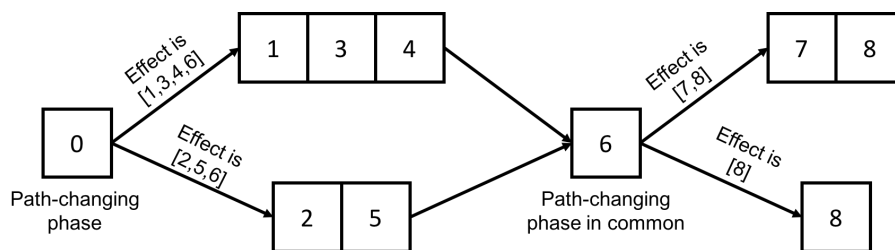


Figure 3.17: Schema representing possible paths a survey can follow, and design considerations to take.

The other types of answers weren’t considered for applying an effect for the harder logic they would require to distinguish answers into groups, and for the added complexity that would be necessarily added the survey JSON specification.

In Figure 3.18 we show how our tool displays all other types of answers, where one should note our attention in following well established conventions or obvious designs.

Both the question with a `select-dropdown` answer, bordered in blue, and the one with a `choose-multiple` answer, in yellow at the bottom, are probably familiar to most readers, following conventions seen across the internet. The others, however, follow less common approaches.

At the top of Figure 3.18, in red, is displayed a question with a `number-input` type of answer. The

Figure 3.18: Interface for questions with the answer types (from top to bottom) “number-input”, “select-dropdown”, “month-input”, “time-input”, and “choose-multiple”.

interface chosen is centered around a simple input field like in most online forms, but grouped with a supporting text to give more meaning to the number inserted, added based on the JSON specification for the question. Also configured in the JSON are the limits to the inserted number, which will contribute to determine the validation of the input on the phase, as we later describe.

`month-input` answers, such as the one bordered in purple in Figure 3.18, are based on the same elements, but instead offering two different number input fields, with predefined supporting text that, since the program knows which type of answer it is rendering, doesn’t need to be specified on the JSON. Both those fields also impose limits on the validation of the numbers given by participants, but this time they are defined in the application code itself, since a month can only vary from 1 to 12, and a year wouldn’t ever be lower than, say, 0 or 1800.

Finally, a `time-input` answer, in green, joins a number input field to a dropdown menu populated with the different time units specified on the JSON. Similarly to `number-input` one can configure lower and upper limits on the inserted number, and the application will assure their validation.

The mentioned validation process can be described as a function that runs every time there’s a change in the answers, and verifies if every answer in the phase was provided and is within the validation conditions imposed by each question’s specification. If there’s **at least one invalid answer**, the function deactivates the “progress button”, requiring the user to first review its answers. While we know it would be best if the interface pointed for the incorrect answer, we weren’t able to include such feature inside the time line of the project, leaving it for future improvements.

While there is one state for each type of interaction, states that cover interactions with maps share a lot of similarities, mainly in their interface.

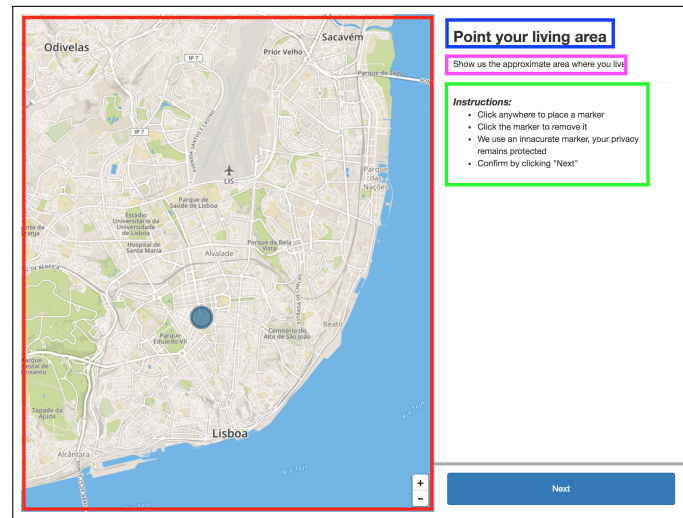


Figure 3.19: Interface elements for every map interaction state.

In Figure 3.19 is pictured the interface for the state of a `point-a-place` phase. You can see, each bordered by different colors, the different elements present in the interface. First of all, and naturally taking up most of the space, is the map, in red, here partially cropped for the sake of saving space. This is what the user will interact with, as everything from pointing places to drawing boundaries happen on top of that map. At the right of the map, you can see a white strip, to each we call “sidebar”. The sidebar serves the role of gathering every supporting element of the phase. These include the title, in blue, the description, in purple, the instructions, in green, and buttons to toggle behaviors and actions on the map (later detailed), in addition to the always present “progress button”, at the bottom.

By going through the common elements in this interface, we are also presented with the functions and features common to all these states. First, of course, is every basic function over the map. These include panning and zooming, as well as its simple initialization and styling. All of these basic functions are automatically loaded as we add a map element to the interface, thanks to the map library we are using, Leaflet.JS.

Other common functions include the already mentioned translation of text from the survey specification into properly formatted text on the interface, like separating paragraphs, and listing and highlighting instructions.

3.4.4 “Point-a-place” and “point-multiple-places” states

As previously mentioned, there are two types of phases that address the point placement interaction, these are the types `point-a-place` and `point-multiple-places`. As expected, there's a state for each of them, that although sharing the same interface, described in Section 3.4.3, setup slightly different interactions with the map.

When a “point-a-place” state is loaded, and after it initializes the map, a callback is added to the map. This callback is activated when there’s a click on the map, and places a circular marker of fixed width at the place the user clicked. An example of what the marker would look like was introduced in Figure 3.19 of Section 3.4.3. The callback function also takes into account the requirement that only one marker can be present in the map at a time, and thus makes sure to remove previous markers whenever a new one is added.

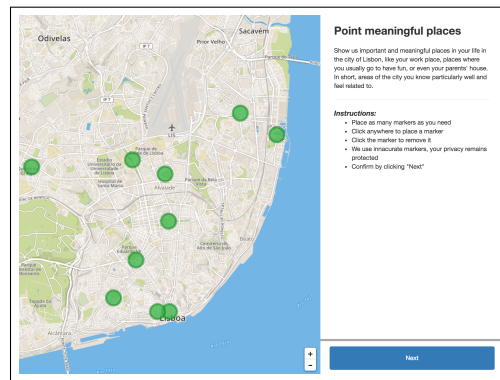


Figure 3.20: Interface for a “point-multiple-places” state. Note that users can place as many markers as desired.

A “point-multiple-places” state, on the other hand, would setup a slightly different callback. The difference is that this drops the condition to eliminate previous markers anytime a new marker is placed, and thus allowing the user to “point multiple places” on the map, as observable in Figure 3.20.

In addition to the callbacks on the map, we also thought it would be useful to provide each marker with its own associated callback function. This is triggered on click and eliminates the marker. This is most useful for point-multiple-places phases, but also works on the other type. As we recon this to be an invisible feature, we recommend any survey designer to include it in the phase instructions.

3.4.5 “Draw-area” state

The state for a draw-area phase required more careful implementation. As the interaction in question is around drawing boundaries, we had two options: either allow free-form drawing, or point-to-point drawing. The first is close to drawing on paper, the second limits most creative forms, as users can grow tired when having to delimit a great or more round area (e.g. making a circle out of a polygon).

In spite of possible difficulties when later analyzing the data, we chose the first option, in order to guarantee a more user-friendly interface. To implement it, we resorted to Leaflet.FreeDraw, a library that works on top of Leaflet.JS and implements the free-drawing functionality. A user can draw a free-form shape by simply dragging the mouse over the map. When releasing the mouse button, an algorithm is run, replicating the shape the user drew as a polygon with a limited number of vertexes.

An example of such approximation is shown in Figure 3.21, where the polygon on top of the map was generated as a reasonable approximation of a drawing. As one can note, the result is detailed enough to represent accurately the originating drawing.

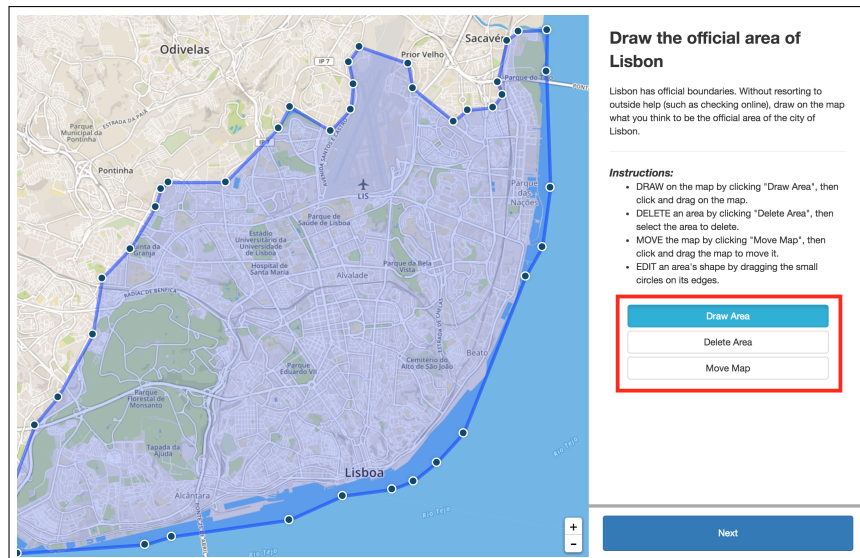


Figure 3.21: Interface for a “draw-area” state, and an example of a polygon resulting from a drawn shape.

However, since the drawing interaction is activated through dragging the cursor on the map, it overrides the panning of the map, and was thus necessary to come up with a way to combine the two. We did this by resorting to Leaflet.FreeDraw’s “modes”, which follow a state approach to what interaction are activated. This way, we created a “Move Mode”, a “Draw Mode”, and a “Delete Mode”.

The draw mode covers the already described interaction. The move mode is basically a mode where the library’s features are deactivated, and thus the map behavior returns to normal, e.g. click and drag to pan. The delete mode allows the elimination of entire drawn polygons with a simple click on top of each one. When in delete mode, since the drawing interaction is disabled, is also possible to pan the map in the usual way, however, to keep a good level of usability, we still created the “Move Mode”.

Each mode can be activated through a set of buttons that this state adds to the interface, see Figure 3.21, bordered in red. Each of them is mutually exclusive, implying that every time a user presses one, it deactivates the others.

Note that every mode supports the edition of the shape by dragging its vertexes, a feature also directly provided by Leaflet.FreeDraw.

Once again, considering all the different invisible interactions, such as click and drag to draw, we recommend every one that creates a survey to include the due instructions in the specifications, as shown in the picture.

3.4.6 “Draw-multiple-areas” state

The state for a draw-multiple-areas state is relatively simple, as it leaves most of the logic for its draw-area sub-phases.

This type of phase is only a way to display, on the same step, several neighborhoods or areas that the user can choose to draw. As such, it’s only required to list those options, loading the corresponding phase every time one of them is selected by the user.

You can see the interface we created for it in Figure 3.22, and how we decided to display the drawing

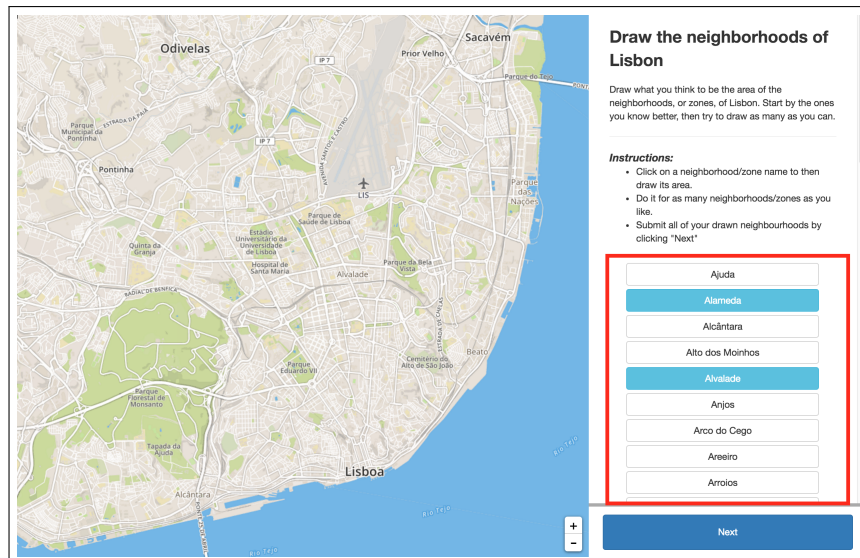


Figure 3.22: Interface for a “draw-multiple-areas” state. Note that for this particular case the user has already drawn “Alameda” and “Alvalade”.

options. We used a button for each neighborhood, that when pressed leads to a “draw-area” state like the one from Figure 3.21 on Section 3.4.5. On that sub-phase, when the user finishes drawing and presses the progress button, it is lead back to this state, but with the previously explored area marked in blue, to indicate it.

3.5 Data Analysis Tool

The second main part of our framework is the web-app used to analyze the results. Here we describe how the code is structured, the most important algorithms, and the different interface elements.

As we aimed to implement the listed requirements in Section 2.5, we came up with a tool with 4 different main screens: the dashboard, the analysis screen, the report screen, and the correlation analysis screen.

The first concerns the overview of the different phases of the target survey and the general results for each of them, allowing the researcher to select the due phases to analyze.

The analysis screen is where most of the work is done. Here, researchers compile and process the data gathered by the survey, filtering it as needed, and configuring the results on display.

The report screen is where researchers have an overview over the saved results, and can either download the processed result or export the raw data.

Each screen, similarly to the other app of the framework, is a state on a state machine pattern (see beginning of Section 3.4). The mentioned “analysis screen”, however, adds an extra layer of detail, having a set sub-states, each of them loaded depending on the type of data being analyzed, as detailed further down.

Also based on the previously specified requirements, we identified a set of features. These are:

- **Filters:** allowing the selection of subgroups of participations by applying conditions over the data

gathered by the survey.

- **Snapshots:** images rendered from the results. Can be downloaded and later used on reports or studies.
- **Correlations:** calculates several measurements on each participation. These range from agreement over an area, to distance between points and an area. It then allows the researcher to export that data under a `.csv` file, thus supporting correlation analysis with a third party program.

Next, besides a description for each state, we also expose some crucial algorithms and functional parts of this tool. We highlight the filtering system and algorithm, as well as the algorithm for the results' processing for each type of data.

3.5.1 The Dashboard

The dashboard is the initial state of the Data Analysis Tool. Researchers reach it immediately as they load the tool, and are presented with an overview of the different phases of the survey being analyzed.

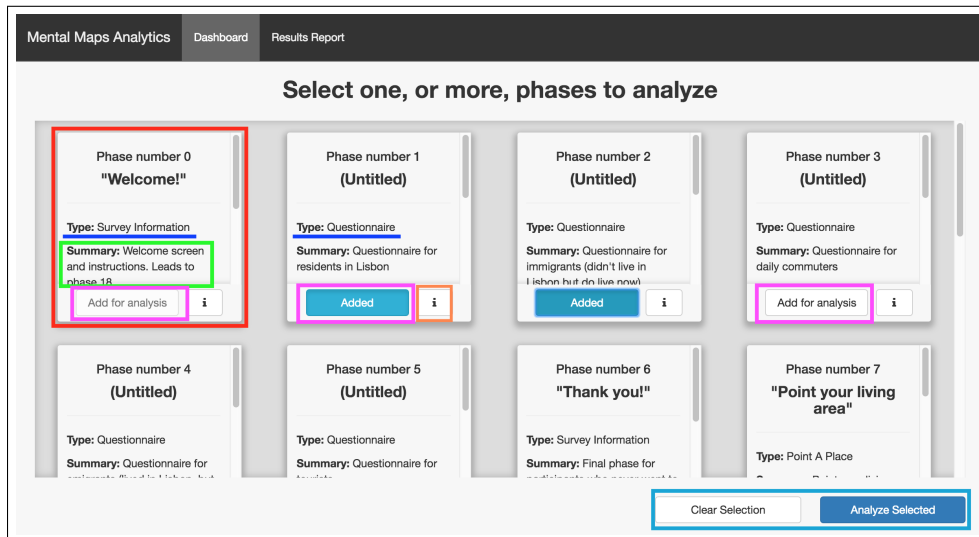
As you can see from Figure 3.23(a), the dashboard displays each phase as a thumbnail, here highlighted in red. Besides the number of the phase on the survey array, and its title, a phase thumbnail also displays the values of the `type` and `summary` properties, respectively highlighted in blue and green on the top-left thumbnail. These help the researcher easily distinguish between phases and more rapidly carry with their analysis.

In Figure 3.23(b) we can see what else each thumbnail displays. It consists of general stats of the phase in question, and serves the purpose of indicating to researchers whether its worth it to analyze the participations in that phase.

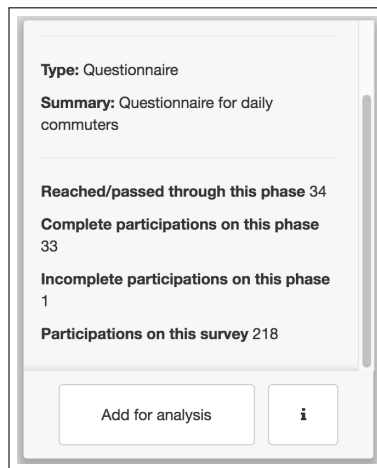
Finally, for each thumbnail there are two different buttons. The smallest, bordered in orange in the second thumbnail Figure 3.23(a), when clicked, displays a modal window with an extensive description of the phase of the thumbnail. This includes specifying each user-addressed property and its value on each phase's JSON specification. The greater button on the left of it, highlighted in purple on three different thumbnails in Figure 3.23(a), serves as toggle that switches the addition of each phase's participation data to the data to be analyzed.

As you can see, it is possible to add more than one phase's participation data at a time. This is only possible, however, for some type of phases which participation data is compatible between them. This is the case for phases of type `questionnaire` with phases of the same type, for `point-a-place` phases with themselves and with `point-multiple-places`, and for `draw-area` phases with themselves. As you can see by comparing the state of the different buttons, the interface treats this compatibility by keeping compatible phase's buttons active, and deactivating those from incompatible phases.

When researchers end selecting the phases for analysis, they then may press the button "Analyze Selected" to load the due analysis screen and state. If, however, they change their mind, there's a "Clear Selection" button to quickly deselect every phase. These buttons are separated from the rest of the thumbnails, as can be seen in Figure 3.23(a) in light blue, on the lower-right corner.



(a) Interface of the dashboard screen.



(b) General stats for a phase, in its thumbnail.

Figure 3.23: The different elements on the dashboard interface.

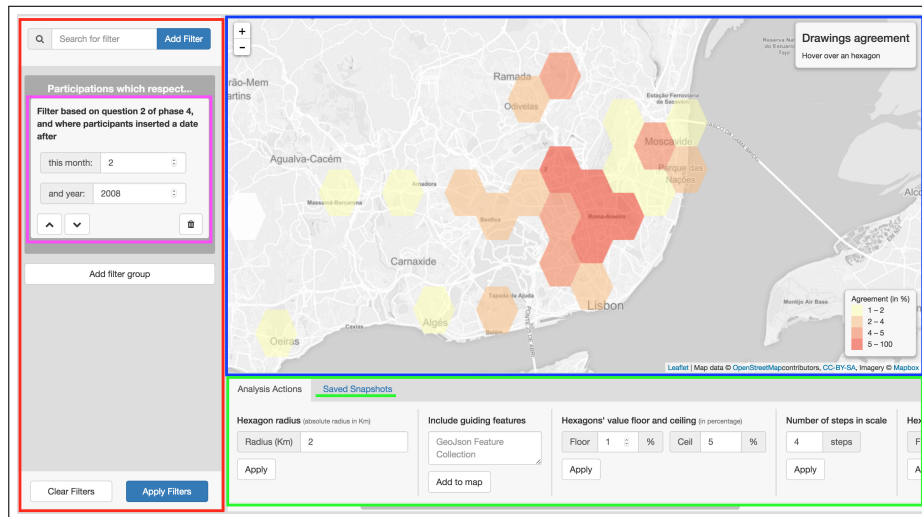
3.5.2 The Analysis Screen

As researchers press “Analyze Selected” on the dashboard, as described in Section 3.5.1, they are taken into the analysis screen.

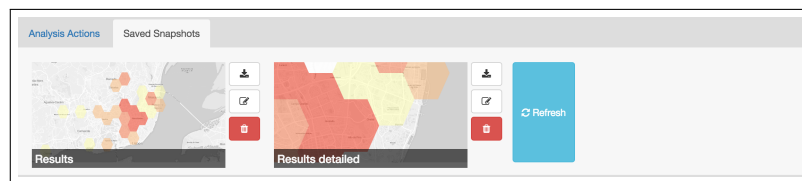
The analysis screen is where every type of analysis to the results are actually made. Here, researchers see how participants drew their areas, where they placed their markers, or what were their answers. It’s also in this screen where it is possible to filter participations, selecting them depending on the values introduced in some other phase. In this screen, basically, users can filter, process, style, and save the results.

However, as stated in Section 3.5, the analysis screen is not a simple state, and instead has sub-states of its own. These sub-states vary with the type of data that’s being analyzed, and they provide the functions that are specific to process and style each of those types.

Nevertheless, as the parent state, the analysis screen has some responsibilities and establishes a common interface.



(a) Analysis screen interface.



(b) Detail of the snapshots bar.

Figure 3.24: The different elements on the analysis screen interface.

We can see the different elements present in the analysis screen in Figure 3.24. There are three main parts. The most important, and taking up most of the screen is the results area, highlighted in blue. In red, at the left, we see the filters bar. Finally, in green at the bottom, is the actions bar and snapshots bar, separated by tabs.

The first of them serves the purpose of displaying the already processed results, and is the part that changes among data types. In this particular example of Figure 3.24(a), the type of data being analyzed is for `point-a-place` and `point-multiple-places` phases, which processing algorithm we explain later. It's in this screen area that the user fit the looks of the results to the desired ones, in order to obtain the best representative snapshot, a feature later detailed.

The second area of the screen, the filters bar, contains both the necessary actions to add, edit and delete filters. Filters is what we call to each condition set upon the set of participation data, contributing to the duly selection of a subgroup of participations, as explain in a future section. Highlighted in purple, we can see how a filter is represented in the interface.

Finally, there is also a bar at the bottom that serves two different purposes. It can display, with the "Analysis Actions" tab selected, a series of configuration options or actions that are applicable to the displayed results on the "results area". It can also show, with the "Saved Snapshots" tab selected, the different snapshots taken on the results, see Figure 3.24(b), where it is also possible to edit their name, delete them, or download them.

The analysis screen, as parent state, accumulates some functions that are independent from the type of data being analyzed. As such, it's this state that is responsible for the **creation, edition, and execution of filters**, as well as the **creation and management of snapshots**.

3.5.3 Analyzing data from “survey information” phases

As seen in Section 3.3.1, when a participant goes through phases of type `survey-information` there are two options regarding the produced input. Either the phase has no interaction, and thus no input is produced, or the phase contains a `followup` option for introducing an e-mail, then producing an input object with that e-mail address as value.

When on the first case, the results screen simply displays an informative message saying “The selected phases provide no analyzable data.”, thus offering no configuration or actions over the results.

On the other hand, when the phase specification contains a `followup` property, as the analysis sub-state responsible for data originating from `survey-information` phases is loaded, it's displayed a simple list of all the e-mails introduced on the selected phases.

This sub-state provides no options of configuration or actions over the results, leaving researcher an only option of “copy-pasting” the email list.

3.5.4 Analyzing data from “questionnaire” phases

Phases of type `questionnaire` produce widely variable input objects, see Section 3.3.2, as each question produces its own, depending on the type of answer it provides. However, as the answers produced are necessarily quantifiable, by our design decisions, they can all be displayed under the same form: a bar chart. The bar charts were easily generated and supported thanks to an external library, Chart.JS, ported to Angular.JS¹².

As a `questionnaire` phase is composed of a variable number of questions with different types of answers, we decided to process its results on a question-by-question basis. We display the results for each question separately, and adapt them to the type of answer for the question.

Figure 3.25 shows an analysis screen when analyzing data from a `questionnaire` phase. We can see that the sub-state displays the questions on top of each other on a scrollable section. For each of them, it shows the question body and the index of both the phase and the question, on each respective array, underlined in red in 3.25.

Under the question body, we can see the generated bar chart, and on its right, in green, the chart configuration. Both these elements vary with the type of answer for that question. Also, in purple, is the button that captures the graph and renders it into a snapshot, adding it into the “snapshots bar”, at the bottom of the screen.

In Figure 3.25, the fully visible graph shows how questions with an answer of type `number-input` are processed. The bar chart is divided into intervals, where each of them counts the number of participations that inserted a number in between the limiting levels, including both the lower and upper one. Its configuration consists in changing the numbers that define the levels to, for example, showing how many participants are over 18, and how many are under.

Both questions with `month-input` and `time-input` follow similar approaches, as their input is also composed by numbers, and need only to accommodate the different data formats on the configuration,

¹²<https://jtblin.github.io/angular-chart.js> last visited on 15.10.2016

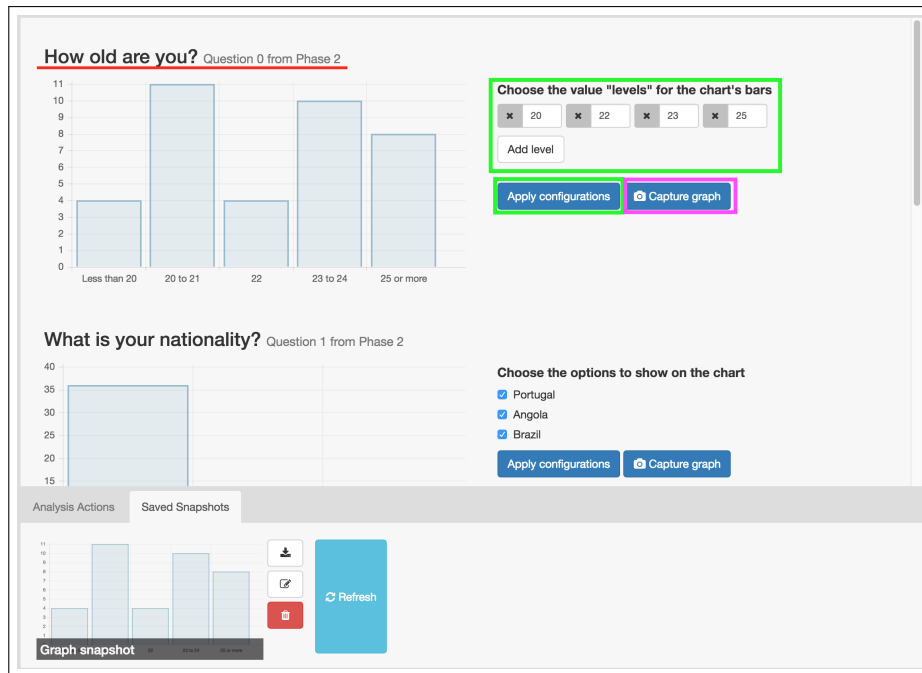
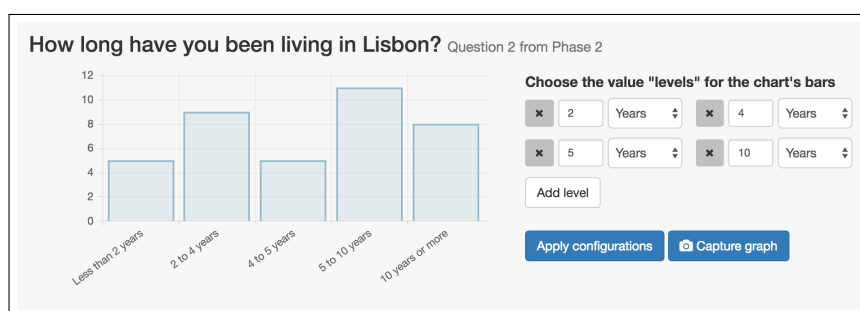


Figure 3.25: A possible analysis screen for a questionnaire phase. The fully visible graph corresponds to a question with a “number-input” answer.

as you can see from Figure 3.26.



(a) Displaying results for a question with “month-input” answer.



(b) Displaying results for a question with “time-input” answer.

Figure 3.26: Results for “month-input” and “time-input”.

For these three types of answer, as the results are loaded on their respective area, the “questionnaire” sub-state generates, for each graph, a set of 3 levels, based on the first, second, and third quartiles of the respective data.

The other three types of answers, choose-one, choose-multiple, and select-dropdown, follow a different approach. For them, each bar represents how many participants chose the option with the

same name. The chart configuration allows to show or hide the bars for some options, that may not be appropriate to show. In Figure 3.27 we see the resulting chart for any of those.

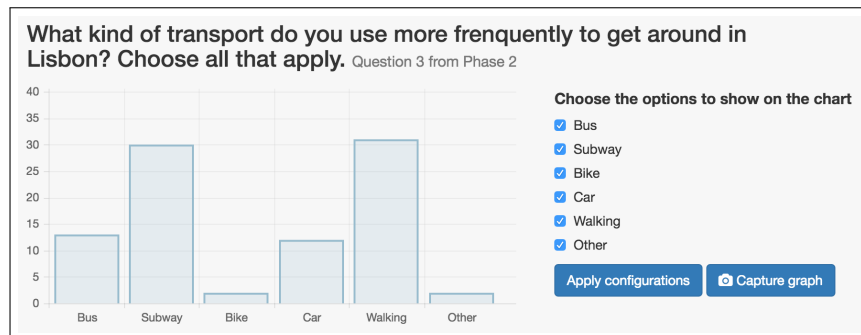


Figure 3.27: A possible chart for results to questions of either “select-dropdown”, “choose-one”, or “choose-multiple” answer types.

Among these three last types, the only differences are in the initialization of the charts. While charts for answers `choose-one` and `choose-multiple` have one bar per available option in their specification, charts for answers `select-dropdown` only show the bars for options that were chosen at least once among the data under analysis, thus supporting cases where there are a lot of options, like a dropdown with every country in the world.

Finally, we should note that, since each chart is separate from each other, there are no common actions or configurations to be shown on the “actions bar”, thus deactivating the respective tab.

3.5.5 Analyzing data from “point-places” phases

As described in Section 3.3, phases of type `point-a-place` and `point-multiple-places` produce identical input, consisting of a GeoJSON “FeatureCollection” of point features. As such, the resulting data from these two phases is compatible, allowing their analysis simultaneously, and thus only requiring one analysis sub-state for both of them, to which we call “points” sub-state.

One of the best ways to compile and process results from points on a plane is through some derivative of an heat-map, by showing where there’s a greater concentration of points. Between the different options, we opted for a binning algorithm, where points are included into “bins” of pre-defined sizes depending on their position on the map, for our case. These bins then take certain colors, or change size, according to the amount of points they include.

For our specific implementation, we used hexagon-shaped bins regularly tessellated over the map. Hexagons represent several geometric advantages over, for example, square bins, like more efficient covering of a plane, and end up providing a better sampling efficiency. Besides, they represent a less biased way to display densities than other regular tessellations¹³.

The result of this processing can be seen in Figure 3.28, where we can see hexagons of fixed sized but varying color, the approach we chose to follow.

¹³Based on the work Lewin-Koh in https://cran.r-project.org/web/packages/hexbin/vignettes/hexagon_binning.pdf last visited in 15.10.2016

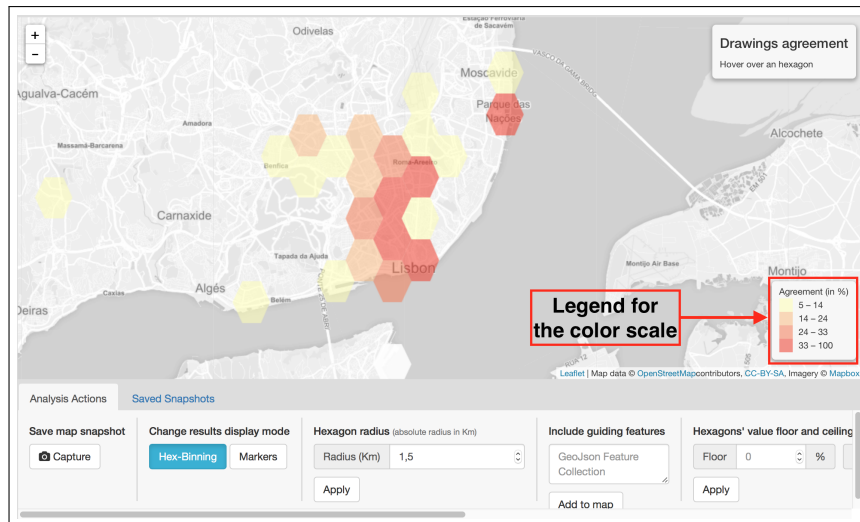


Figure 3.28: A possible result of the processing of points into an hexagonal grid.

The algorithm starts by laying a grid of hexagons with a given radius over a calculated bounding box of all the points present in the data. Then, for each hexagon on the grid, it goes through every participation data. As soon as it finds a point inside the hexagon's area, a counter specific to that hexagon is incremented. That counter takes only into account the number of participations that have a point inside of it, not the total number of points, which means that after finding a point inside its area, the algorithm skips to the next participation. After cycling through each participation, the counter of the hexagon is then divided by the **total number of participations**, resulting in a normalized value between 0 and 1, which in turn represents the participations' agreement in the area of that polygon. That agreement it's what will define the color of the hexagon, by applying it to a color scale. A description of this algorithm in pseudo-code can be seen in Listing 3.1.

Listing 3.1: Algorithm for producing the “points” results

```

1  bb = boundingBox( allPoints )
2  hexagonalGrid = generateHexGrid( bb )
3
4  for each hex in hexagonalGrid
5      participationsInHex = 0
6
7      for each placedPoints in participations
8          if any placedPoints inside hex
9              participationsInHex++
10             continue //to next participation
11         end participations cycle
12
13         agreementInHex = participationsInHex / numberOfParticipations
14         colorOfHex = colorScale( agreementInHex )

```

To implement this algorithm we resorted to yet another library, Turf.JS¹⁴, that offers a great set of functions for geo-spatial analysis, like the hexagonal grid generator, and the function to check if a point is inside a polygon.

As well as presenting the results through an hexagonal grid, this sub-state can also display the results by simply rendering all of the placed markers on the map, at times a better option to analyze them in detail.

Furthermore, in order to offer researchers greater power over the results, the “points” sub-state provides a series of configuration options, which are passed on to the “Analysis Actions” bar at the bottom of the analysis screen.

The most obvious configuration is the ability to change the hexagons’ size, by altering their radius. Here, the hexagon radius represents the distance between its center and its vertices.

Besides their size, researchers should also be able to configure the style of the hexagons, defining their color range and the values they take into account or discard. As such, we added three more configuration actions: “Hexagons’ value floor and ceiling”, “Number of steps in color scale”, “Hexagon color range”. You can see how these options are displayed in the interface in Figure 3.29(a).

(a) Available configuration options regarding the color and value of the hexagons.

(b) Other available configuration options and actions over “points” results.

Figure 3.29: Available actions and configuration for “points” results.

The first of them allows for the specification of a floor and a ceiling for the agreement in an hexagon. The floor is the value from which the algorithm should start coloring hexagons, meaning that any hexagon with an agreement value below that is not colored. The ceiling is the value from where the algorithm should stop calculating the color for the hexagon, in other words, all hexagons with values above the ceiling will all have the same color. This allows researchers to better adapt the results’ style to their data, letting them do things such as set, say, 33% as the “good enough” value of agreement.

The second action works closely with both the first and third. Here, researchers specify how many color levels, or steps, should be between the floor and the ceiling. Values within the same level share the same colors.

The third configuration option allows the specification for the color corparticipant to the floor value,

¹⁴<http://turfjs.org> last visited on 15.10.2016

and to the ceiling level. The colors in between are automatically generated using a “color mixing” function and depend on the number of steps specified on the previous configuration field.

Note that these three configurations are only available when rendering the results as an hexagonal grid. When opting for “Markers”, see button in Figure 3.29(b), these actions disappear from the actions bar.

In addition to the configuration of the hexagonal grid, this sub-state also provides an action that allows the addition of one or more polygons on top of the map to serve as a guide, see the rightmost field in Figure 3.29(b). A good application is to include the official boundaries of an area to allow an easy comparison of the results with the reality.

Finally, there’s a “Save map snapshot” action to render the map into an image, that in turn will be registered into the “Saved snapshots” bar.

3.5.6 Analyzing data from “drawings” phases

When analyzing drawn polygons, the researcher is usually interested in noticing where those drawings intersect with each other, thus uncovering the area of most agreement. As such, for displaying results of draw-area phases – and, consequently, draw-multiple-areas – we also opted for a heat-map-based approach, resorting to a similar algorithm to the hexagonal binning, introduced in Section 3.5.5.

Although the binning algorithm is, by definition, something that is only applied to points, the resulting hexagonal grid can support other types of data, like the number of drawings that intersect themselves over each hexagon.

Since the type of data being analyzed, as described in Section 3.3, consists of one or more polygons per participation, the agreement can be defined as the **number of participations** that drew a polygon over an area, instead of the number of polygons.

The algorithm for processing this data, follows the same general approach of the one used for “points” data, as one can see from Listing 3.2.

Listing 3.2: Algorithm for producing the “areas” results

```
1 bb = boundingBox( allDrawings )
2 hexagonalGrid = generateHexGrid( bb )
3
4 for each hex in hexagonalGrid
5     agreementInHex = 0
6
7     for each drawnPolygons in participations
8         intersectionArea = intersect( drawnPolygons , hex )
9         if intersectionArea > 0
10             agreementInHex += ( intersectionArea / area( hex ) )
11             continue // to next participation
12             // (no polygons from the same participation intersect)
```

```

13     end participations cycle
14
15     agreementInHex /= numberOfParticipations
16     colorOfHex = colorScale (agreementInHex)
17 end hexagonalGrid cycle

```

Again, we begin by finding a bounding box of the drawings, in order to generate an hexagonal grid that covers them all. For each hexagon in that grid, we cycle through each participation, and test if any of the drawn polygons intersect the hexagon. If it intersects, then we calculate the area of intersection and divide it by the area of the hexagon, thus getting a number between 0 and 1 that represents the amount of the hexagon that is covered by the polygon. That number is added to a counter specific to each hexagon, similarly to the algorithm in Listing 3.1. When finishing iterating through all the participations, we then normalize the counter, by dividing it with the total number of participations. Thus, for each hexagon, we end up with how much of it was intersected by all the participations, and color it accordingly, depending on the color scale.

For this implementation, we resorted again to the Turf.JS library, using its functions to find the intersection between two polygons, and the area of a polygon.

Regarding the available configurations for these results, and since this also uses an hexagonal grid to display the results, we chose almost the same set of available configurations as the ones chosen for “points” data, see end of Section 3.5.5, only removing the support for displaying the results as markers, as expected.

We should note that when analyzing a phase of type `draw-multiple-areas` there is only one added step to the results processing and analysis. It consists in selecting the area, or sub-phase, which results are to be analyzed. As those are loaded, the interactions and interface are the same as it would be for a `draw-area` phase.

3.5.7 Filtering results

As mentioned from the beginning of this dissertation, one of the most useful things to do when studying mental maps, is the ability to isolate subgroups of participants, and compare the results between them. To support this feature, we implemented a system of filters, that can be applied over the gathered participations.

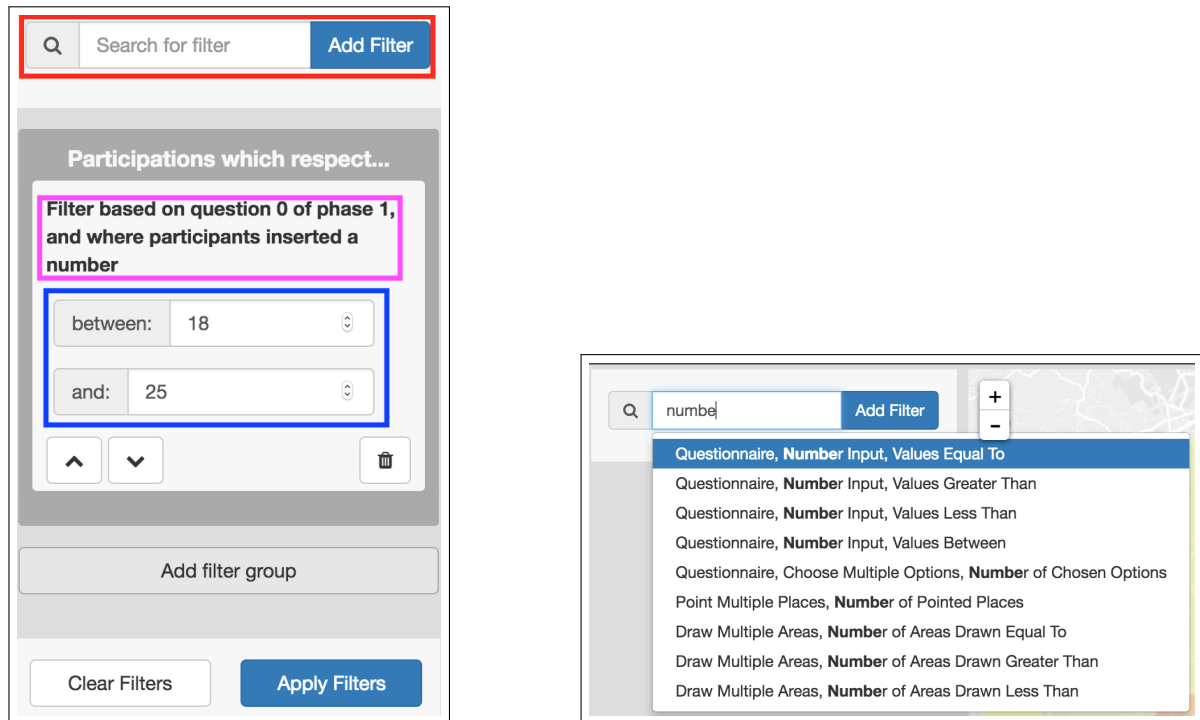
A filter is what we call to a logic condition that is applied over the data provided in a certain phase, testing the values given by each participation and returning only those which are valid under that condition.

Since a filter can be applied to any phase, we had to make them vary with the type of phase they are applied to, creating different conditions for each of them.

To accommodate those factors in our implementation, we decided to represent the filters as objects. They have a name, a description, a designated type of phase and, if appropriate, a designated type of answer. Also, as their core, they have a filtering function.

The filtering function represents the function to run when testing the validity of each participation. A filtering function follows a common structure across every type of filter, receiving as arguments the filter parameters and the participant input in the target area.

The filter parameters are specified in the interface by the researcher, and complete the filter configuration by defining the values that the participations are tested against. In Figure 3.30(a) we can see, highlighted in blue, how the filter parameters are rendered into the interface.



(a) The different interface elements present on the filter bar.

(b) The “typeahead” functionality in action.

Figure 3.30: The filter bar interface, and filter searching in detail.

Also in Figure 3.30(a) we have, in red, the search bar, where researchers search a filter they want to add, and, in purple, the summary of the filter.

The complete process of applying a filter begins with the search of the desired filter on the search bar, resorting to the “typeahead” feature built into the bar, as demonstrated in Figure 3.30(b). After searching for the desired filter by its name, researchers then must select the phase to which it applies. After that, the filter is added to the filter bar, where the only thing left to do is configure the parameters.

The parameters are specific to each filter, possibly varying in number, and taking different types of values, such as numbers or options.

Once again resorting to Figure 3.30(a), we can see that below the only added filter is the button “Add Filter Group”. A filter group is what we call to a group of filters that share an “AND” logic between them, meaning that each one of them will **filter the data originating from the participations selected by the previous filter**. Between filter groups, however, there’s an “OR” logic, meaning there’s an **union of the resulting set of participations from each group**. An example can be seen in Figure 3.31, showing the two different combinations. On Figure 3.31(a), the specified filters select participations that both entered a number between 18 and 23 on question 0 of phase 1 **and** that also chose the option “I

don't live in Lisbon, but I work/study there (daily commuter)" on question 0 of phase 18. Figure 3.31(b), on the other hand, shows a set of filters that select participations that inserted a number in the same range **or** participations that chose that same option.

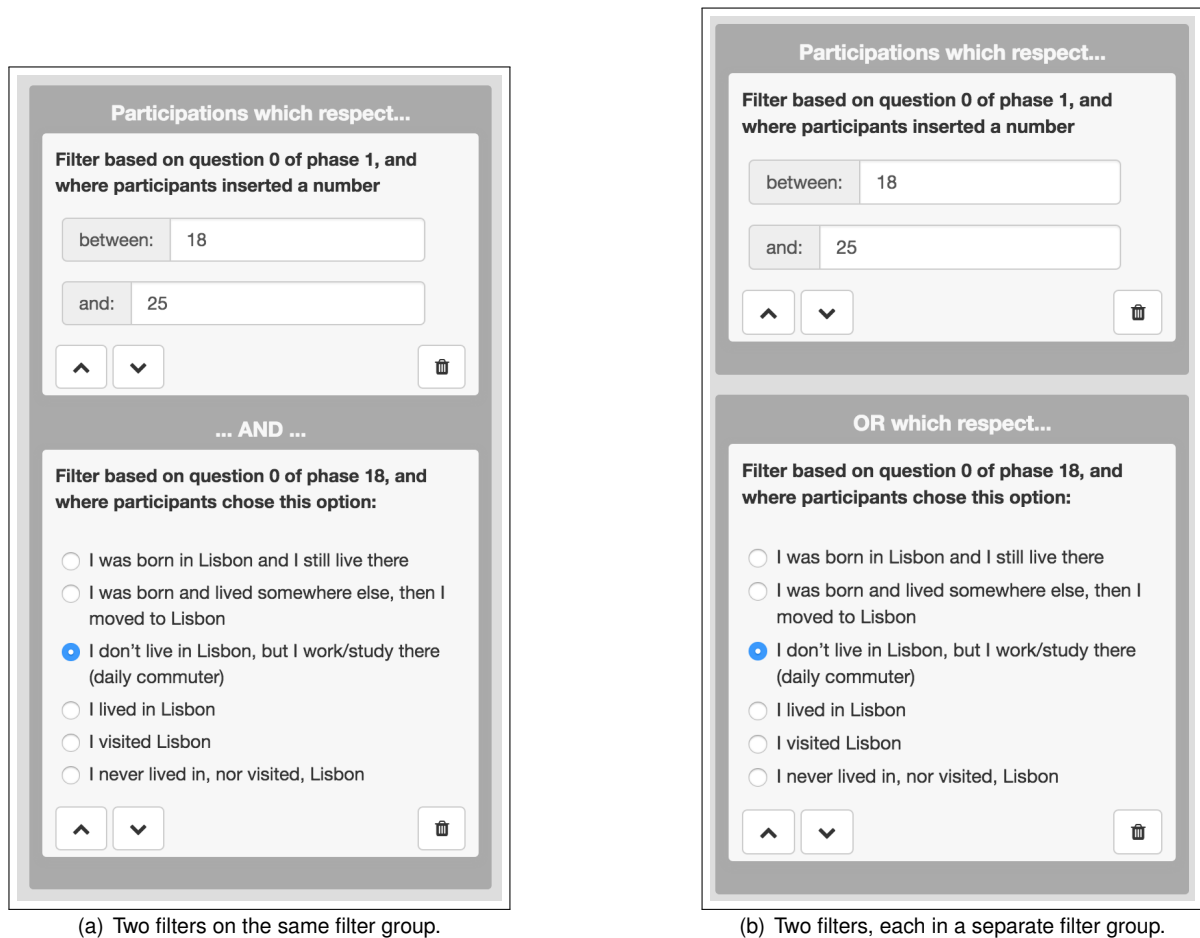


Figure 3.31: Filters in filter groups.

As filters are applied, a resulting set of participations is returned, and then passed on to the active analysis sub-state, described in the previous sections. As that sub-state notices the change in the participations under analysis, it executes its results processing algorithm one more time, updating the results area of the screen.

3.5.8 Results report and correlation analysis

As researchers capture snapshots of the results, they are added to a separate entity that is responsible to keep the snapshots and associated data in a list. This list can be consulted on the "Snapshots Bar" of the analysis screen, and also on a dedicated screen to which we call "Results Report". It serves the purpose of providing an overview of the saved results, while also offering some actions over them.

For each snapshot, it's displayed the image of the results, its title, and the information about which phases originated it. Regarding the actions over each of them, it is possible to edit their title, download the image, or delete a snapshot. These elements can be seen in Figure 3.32

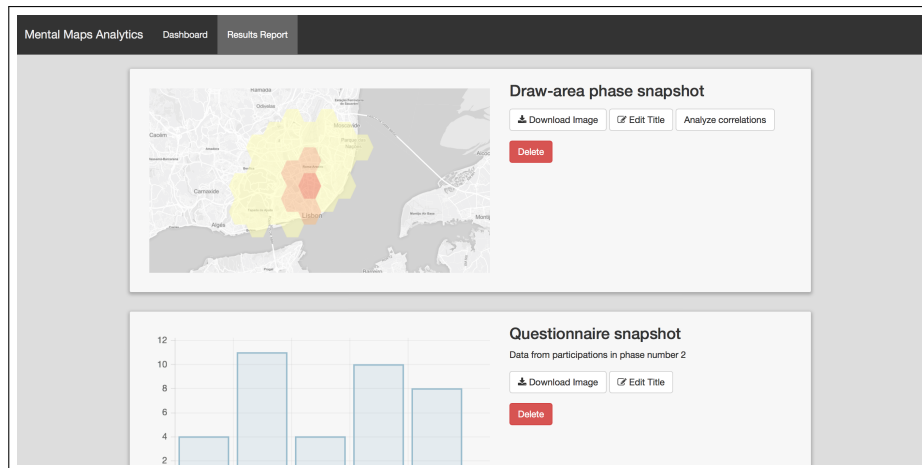


Figure 3.32: The interface on the report screen.

Furthermore, as defined by the requirements listed in Section 2.5, we introduced in this screen the ability to export data in a way to support correlation analysis. We decided to include that feature here because it is something only interesting to do when researchers already filtered the results to a relevant subgroup.

To load the feature, we provide a button “Analyze Correlations” along with the other actions for the snapshot. However, we decided to only show the button for snapshots that originated from phases of type draw-area or draw-multiple-areas, since the areas drawn by a participant are the only type of data that we identified as interesting to correlate with other variables.

When pressing the button “Analyze Correlations”, one last, separate screen is loaded. Here, researchers are prompted to calculate the agreement between the drawings saved in the snapshot and some other area. This other area, that we call “reference area”, will most likely represent some official boundaries of a city or district, but researcher can use any polygon duly specified in GeoJSON.

Figure 3.33: The interface on the correlations analysis screen.

As the reference area is pasted into the due input box, researchers can choose to simply export the data of the agreement between each drawn area and the reference area by pressing the “Calculate Measurements” button, see Figure 3.33. This produces CVS-compatible data that consists of a long

table with a row per participation, where is presented both the agreement between that participation's drawing and the reference area, and the size of the drawing. That agreement represents the percentage of the reference area that was covered by each drawing, while the size of the drawing is presented as its area compared to the geometric area of the reference area, in percentage.

In order to add more correlatable measurements, we also offered the option to include the distance between pointed places and the reference area, for example, to know if someone that places points inside the reference area, draws it better than someone who doesn't place them there. We implemented two different measures, one for `point-a-place` phases, and another for `point-multiple-places`, but with the same result: a distance in kilometers between the closest point placed by the participant, and the reference area. If the point is inside, it returns 0.

Finally, in order to allow the mentioned "correlation analysis", we offer the possibility to load the resulting measurements as a CSV file, widely supported by different analysis tools.

On an end note, we would like to point that the considered participations for the calculations are the same as the ones that originated the snapshot in the first place. This means that researchers can form subgroups on the analysis screen and then apply this type of analysis separately.

Chapter 4

Case Study: mental maps of the city of Lisbon

We needed to validate both the effectiveness and usefulness of the framework. To do so, we decided to apply it to the city of Lisbon, Portugal, and its mental maps. Lisbon is a big enough city to have different ideas associated with different areas – as in an “offices area”, a “leisure area”, etc. Furthermore, Lisbon sees its population almost double in size every workday¹, when people living in adjacent cities move there to work, adding to the tourism that’s been growing at almost 10% every year for the last 5 years². All of this together provide the possibility of very interesting results with a lot of different perceptions of space.

4.1 Survey design

Our case study followed the same basic approach as “Crowdsourced neighborhood boundaries”, analyzed in Section 2.2.1, identifying the different views on neighborhoods’ boundaries, as well as Lisbon’s. However, we also were sure to design the study in order to make it possible to explore, as much as possible, the reasons that led participants to draw the boundaries as they did. This was something that was missing from the mentioned work, and it can completely change how we see mental maps and space perception. Our study thus prioritized the possibility of a flexible analysis of the results, asking for each respondent’s background as extensively as possible, and in different ways, later specified.

We began by creating a first page where we would ask for the participant situation towards Lisbon. One would opt between:

- “I was born in Lisbon and I still live there”
- “I lived in Lisbon”

¹According to http://observatorio-lisboa.eapn.pt/ficheiro/LISBOA_EM_NUMEROS_2014_final_01.pdf last visited on 01.10.2016

²According to http://www.cm-lisboa.pt/fileadmin/Noticias/ficheiros/Apresentação_Resultados_ATL_VN.pdf last visited on 01.10.2016

- “I was born and lived somewhere else, then moved to Lisbon”
- “I don’t live in Lisbon, but work/study there”
- “I visited Lisbon”
- “I never lived in, nor visited Lisbon”

This separated right away the participants into 6 important groups, which we shall call from now on, respectively: “residents”, “emigrants”, “immigrants”, “commuters”, “tourists”, and “strangers”.

Each “type” of participant was led to a different page, customized to his/her situation, where basic background questions are made. The exception is for “strangers”, who were dismissed right away, not being useful for our study. For the others, we asked for age and most used mode of transportation, regardless of the profile, since both seem relevant for every type of situation. “Residents” were only asked for those two things, since we found no use of exploring anything else at that stage.

For “emigrants” we needed to classify their closeness with the city, and thus we asked for how long they had lived in Lisbon, and until when (someone who lived in Lisbon until recently probably has a different perception from other who lived there until the 80’s, for example). We also wanted to separate Portuguese emigrants from others, and thus we asked for their nationality. For both “immigrants” and “commuters” the same idea was followed, as we questioned participants about for how long they were living, or working, in Lisbon. “Immigrants” were also asked for their nationality.

“Tourists” required a greater number of questions, but all were made with the common goal of classifying their experience with Lisbon. To achieve this, after asking for their nationality, we asked them how many times they had visited Lisbon, an approximate total of days they spent in Lisbon, and a general classification of their visits to Lisbon (work/leisure).

These questions guarantee the existence of enough data to duly analyze drawn areas, offering the possibility of relating space perception with experience, age, or type of transport, or even all of them at once. However, we found the need of gathering more information on each participant. Based on our research, see Chapter 2, besides the type of transport used, we knew that the place where one lives, and the places he visits most, also play an important role on space perception. To address this, we added two more phases to our survey: one where the participant is asked to point, on a map, his living area, and another where he points several meaningful, or just frequently visited places.

The first phase was basically the same for every type of participant but “commuters”, these were led directly to the next step (note that they don’t live, or have lived, in Lisbon). Some changes were made in regards to the text presented to each participant type, such as using the past tense for those who don’t live in Lisbon anymore (“emigrants”), or, for tourists, asking instead the place/hotel where they last stayed.

The second phase differed among types also only in text. We asked people who currently live, or work, in Lisbon for pointing important places, such as their work place, a friend’s house or a family member’s house where they spent more time, their favorite cafes, or the most cherished sites. As for people who don’t live in Lisbon anymore, we focused on referencing the places they still remember as being special and having any meaning. For tourists, we tried to direct them to point the places that

marked them the most: a monument, a viewpoint over Lisbon, a particular street or garden, etc. All of this serves the purpose of, once more, backing up claims and conclusions. A participant that points multiple meaningful places in a certain zone probably has a better perception of that area, and what he draws should be especially taken into account for showing how people familiar with that zone “feel about it”.

In both these steps the markers have a buffer zone with a radius of 250 meters. With this decision, in conjunction with the guaranteed anonymity, we hoped to make an otherwise quite personal survey into a more relaxed one, where participants wouldn’t hesitate to give out such personal information.

Finally, the three final phases challenged the participant to draw various boundaries on the map. First, Lisbon’s official boundaries, then, the limit of different areas with which the participant feels familiar, and at last a phase where one could choose multiple neighborhoods to draw. The interaction is simple and the goal straightforward, we want to see what people think about the city’s space, thus our demand for the official boundaries of Lisbon to right away have a minimal insight on the general perception of what is Lisbon and what isn’t. Next, the Lisbon with which the respondent is familiar with, provides the possibility of finding, through those boundaries, not only which parts of the city are more welcome to everybody’s quotidian, but also which areas are still under-used or unexplored.

The neighborhoods phase had a more interesting creation process. To decide on the list of draw-able areas, we published a small online form beforehand, where respondents would simply list all of Lisbon neighborhoods or areas that came to their mind. The most mentioned ones, provided that they wouldn’t overlap each other too much, were chosen to feature on our survey, making up a list of almost 50 areas that we trusted people would know well enough. Interestingly, the list ended up featuring, among neighborhoods, areas which have no official boundaries, and exist only on one’s mental map. A good example of this is Lisbon’s Baixa, which general area is known to everybody, but for which specific boundaries are not clear. Thus, in addition to official areas of parishes (known as “freguesias”) that follow the idea of the “Crowdsourced neighborhood boundaries” study of Boston and its respective goal, we try to specifically uncover mental maps using this simple method of boundaries drawing.

We should add that, in order to restrain the amount of corrupt participations, we limited the area of the map to what we considered great enough boundaries to include honest opinions but eliminate junk data from less serious participants.

4.2 Results

From March 15th until April 4th, 2016, we had 224 participations in our survey, although only 183 had at least some analyzable data. We attribute this latter phenomenon to the fact that the survey is not made for mobile, something we warn people about right on the welcome screen, and probably prompted them to exit the survey, leading to an empty registry on the database for that participation: accountable, but not analyzable. Furthermore, even though a sizable amount of people began the survey, not all of them completed it. Fortunately, we predicted such behavior, and made the software register each participation at the end of each step/phase. The survey being extensive, and possibly exhaustive for the

cognitive weight it can have on some people, resulted in only around 93 participants reaching the final “neighborhoods” phase. From those 93, only 53 drew at least one neighborhood.

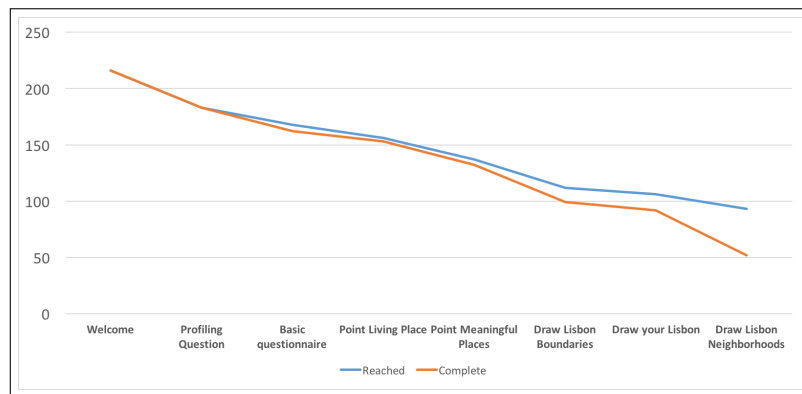


Figure 4.1: Variation of respondents that reached the different phases and completed them.

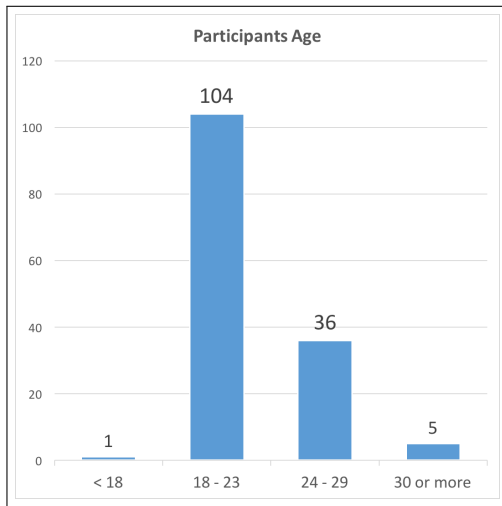
Figure 4.1 shows the progress of both the number of participants that reached a certain step and the number that completed it – participants are allowed to skip the step if they want to, counting in as an incomplete participation, and thus the difference between those two metrics. Although a respondent can choose to try to quickly finish the survey and sacrificing precision in his/her answers, we suspect that these participants felt the pressure to ensure detail in each of the drawn areas. The drop of the “complete” line on the last step backs this theory, probably representing participants that felt tired of drawing on the map. Furthermore, for that phase in particular, confronted with such a great number of neighborhoods, the participants were probably stunned by the amount of drawings they thought they still had to do. Gathering all this together gives us the most probable answer to the quitting/skipping phenomenon. Future versions of this or similar studies may consider advantageous to present questions in random orders to different participants, ensuring a more uniform response level to all of them.

In spite of losing more than half respondents by the end of the survey, the absolute number of complete participations is still high enough to make some insightful analysis, and so we carried on with our work without worrying too much about pushing the survey to more people.

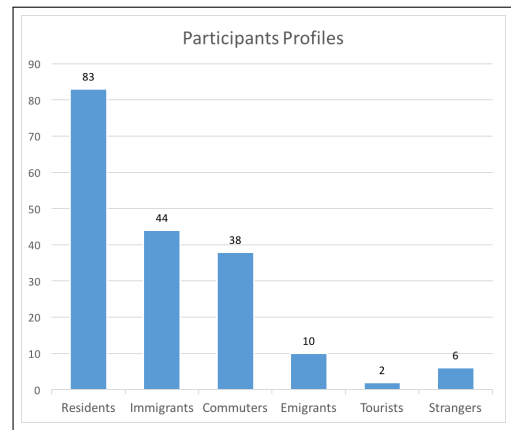
4.2.1 Participants’ background

The survey was published in several social media circles, like Facebook Groups, some related with the city of Lisbon, but most of them directly related with our own college for the potentially big response. We also published on relevant sub-Reddits, such as “/r/SampleSize”. As suspected, most participants probably originated from college, since almost 70% are in the range of “college age”, see Figure 4.2(a). In terms of profiles, and based on the fact that the said college is located in Lisbon, participations were mostly from all time residents in the city, but other profiles such as “immigrants” and “commuters” also have a sizable share, see Figure 4.2(b).

We should also point the lack of “tourists” as unfortunate for a lot of possible observations. However, it didn’t surprise us, since convincing complete strangers with no special motive in participating in an impersonal way, as it is over the internet, is such a hard thing to achieve. The few responses we suspect



(a) Age distribution of the participants.

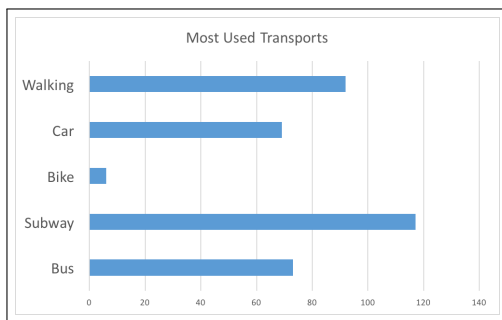


(b) Profile distribution of the participants.

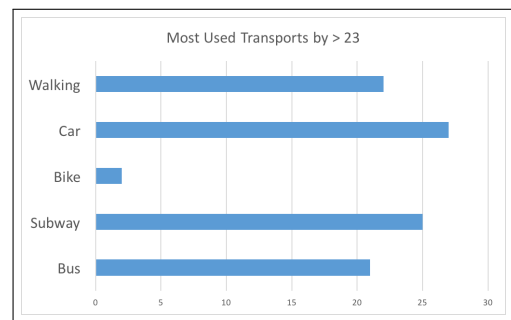
Figure 4.2: General distribution of participants.

that originated on Reddit, or Lisbon related groups, are from people already living in Lisbon. Future studies should take this into consideration and try to approach tourists in a more personal way, like distributing QR-codes on the street with a little verbal introduction.

One question in common to every participant was about their most used types of transport, which they could choose one or more between “Bus”, “Subway”, “Car”, “Walking”, and “Cycling”. The results, in Figure 4.3(a) show that subway is the most commonly used transport system, followed by walking. However, taking into account the overall demographics and situation of our participants, such results were expected. By only analyzing the answers given by participants with more than 23 years, in Figure 4.3(b), suddenly the car plays the major role, although still close to the subway.



(a) Age distribution of the participants.



(b) Profile distribution of the participants.

Figure 4.3: Most used transports.

4.2.2 Participants' living area

Besides the previous factors, the place where participants live is also an important classification of the results, showing the overall tendency for answers on the remaining steps of the survey. We can see that most people said, again unsurprisingly, that they lived in the nearby area of the same mentioned college, see red hexagons in Figure 4.4(a). Besides those nearby areas, there's also the overall distribution

throughout the more residential areas of Lisbon, such as Telheiras, Benfica, and the north-eastern area of the city. There are some interesting observations to make, though, as several markers were placed in curious places. These include the inside of the college campus itself, and the river Tagus. We attribute this behavior to a number of possible situations.

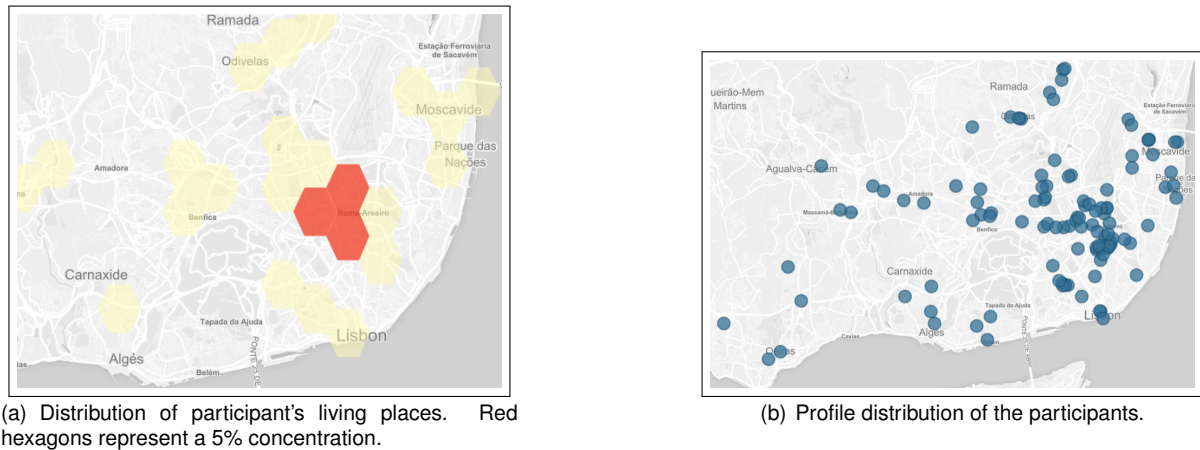


Figure 4.4: Where participants live.

First of all, recall that, even though we created a buffer zone around a marker to respect one's privacy, a person can still feel uncomfortable to give away such personal information as the place where she lives. There's also the possibility, concerning the markers inside the campus, that some participants joked with the fact that they almost live in there. Finally, another explanation is related with the curious fact that some people placed their living area outside of the city of Lisbon, in adjacent cities such as Oeiras, Agualva-Cacém, or Algés (see Figure 4.4(b)). These people are probably what we classified as commuters, but somehow didn't see themselves as so, to the point of saying they live, or have lived, in Lisbon – the only way they could have gone through this step. This, allied with the fact that the map couldn't be panned over some pre-defined limits, see the end of previous section, could have left some participants that live outside of those boundaries, with no other option than placing the marker in some meaningful or central area.

That same group, that stated they lived in Lisbon but their actual living places were put outside of its boundaries, consists of at least 32 people, which gives us right away an idea of what most people identify as Lisbon, and thus their mental map.

4.2.3 Meaningful places and well-known areas

Besides some corrupt data, we can still form a basic image of where most participants live, and what areas they are likely to know better. With this in mind, we move on to explore relations between participants' personal backgrounds, and their perceptions. First off, we must analyze how meaningful places differ with participant. We present the general results in Figure 4.5, on the top-left image, using a low-detail hexagonal grid, where the yellow hexagons stand for a minimum of 3 different participants, and where the darker, red hexagons stand for a minimum of 50% of total participations.

Considering the background of most of them, once again, it's not surprising that the area around

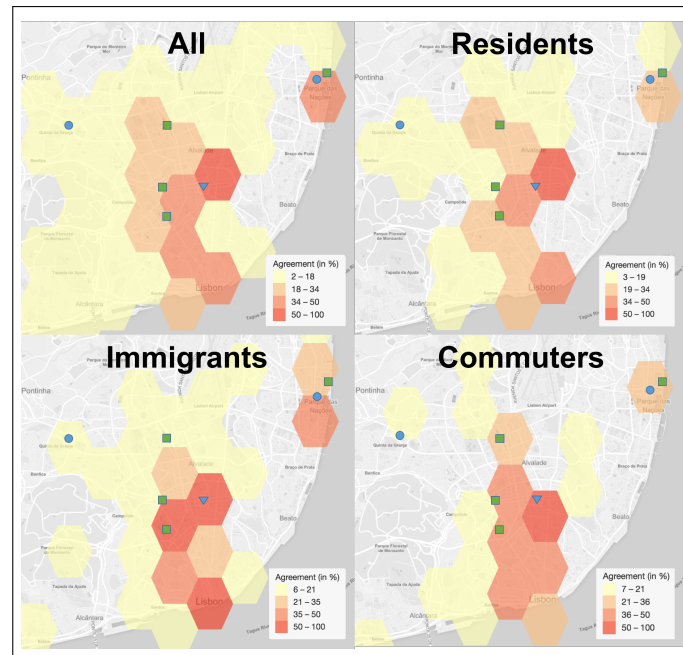


Figure 4.5: Comparison of the distribution of meaningful places across different profiles. Green squares represent parks and large public spaces, blue circles are large malls, and the blue triangle is the college campus.

college, and the college itself is the most marked area. Besides that, we can identify interesting patterns. The most relevant is the “corridor” of darker hexagons connecting Lisbon’s Baixa, Avenida da Liberdade, Avenida Fontes Pereira de Melo, and Alameda/Avenida de Roma (the college campus surrounding area). These can be easily pointed by anyone from Lisbon as the most generally frequented areas, or as the center of the city, due to the amount of offices, restaurants and cafés, monuments, and overall accessibility by transport, which end up gathering residents, workers, students, and tourists alike in the same area. Other than that, there’s a curious, disconnected darker area, Parque das Nações, a relatively modern area of the city, with big exterior spaces and leisure facilities, such as malls and bars. While we suspected from the beginning that this could be one of the most marked zones, the results proved it, and show its importance, even while being disconnected from the “most meaningful part” of the city.

Furthermore, it should be noted how some adjacent areas to the mentioned “corridor” of darker hexagons, can have a drastically lower number of markers. Orange hexagons represent areas where at least 18% of participants placed a marker, so any yellow hexagon is below that level. It is thus curious how 17% or less of participants, or even less than 2% for the uncolored areas, don’t know, or don’t have any meaningful connection to a place so close to another so important.

Since our framework allows us to filter these results as deeply as possible, offering us the possibility to test other patterns and hypothesis, we decided to analyze the differences in placed markers among types of participants, trying to understand how the “important part of the city” vary with the relation that a person has with it. We rendered the results for all profiles of participants but emigrants, and tourists, which in total represent only 5 contributions in this step of the survey, and thus provide no insight on their own.

When comparing the results from commuters, immigrants, and residents, see Figure 4.5, we first get the feeling that the overall difference is not very significant, but while the darker areas are roughly the same (even though there's a difference in their relative meaningfulness), the major insights come from the lighter hexagons. They show how different Lisbon is for residents and immigrants – people living in the city – compared with commuters. Commuters' meaningful places are more concentrated, and around business and leisure zones, leaving more residential, or less central areas unexplored. It appears that commuters tend to deviate less from their usual routes and destinations, while residents and immigrants, appear to have a more widespread knowledge of the city.

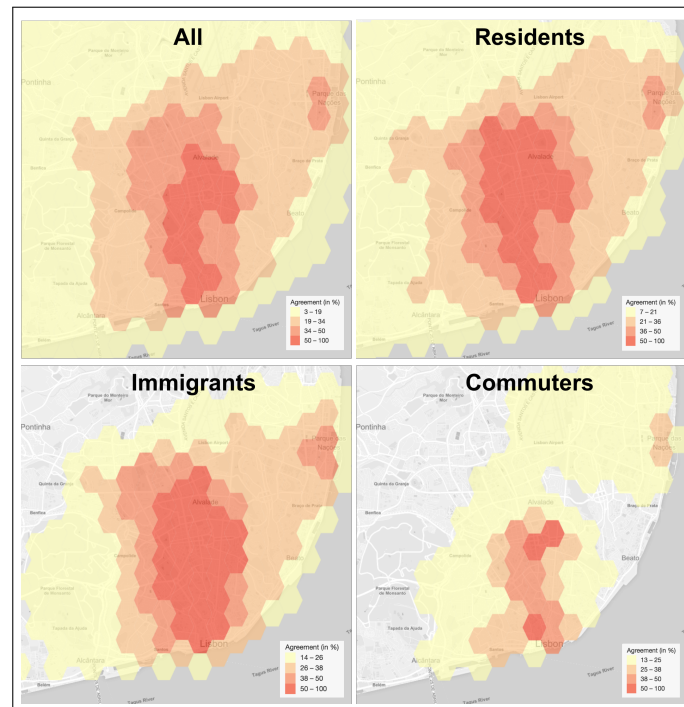


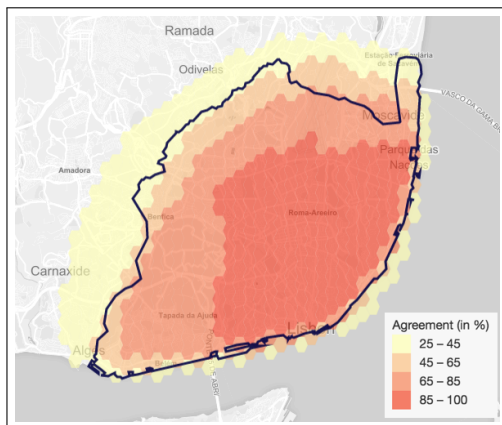
Figure 4.6: Comparison of the drawn areas representing the Lisbon each respondent is familiar with.

The previous observations go together with the results for one of the next survey steps: drawing the area of the city the participant is familiar with. As one can see in Figure 4.6, the same central corridor continues to represent the most relevant area of Lisbon, and Parque das Nações, to the east, continues to be the same disconnected exception. Furthermore, it strengthens the topic on how the city perception can vary with the relation one has with it. Once again, residents and immigrants included a large area of the city as familiar, while few commuters did the same, concentrating over the same area. Overall, this points for the existence of a correlation between one's most meaningful places, and the area he's familiar with.

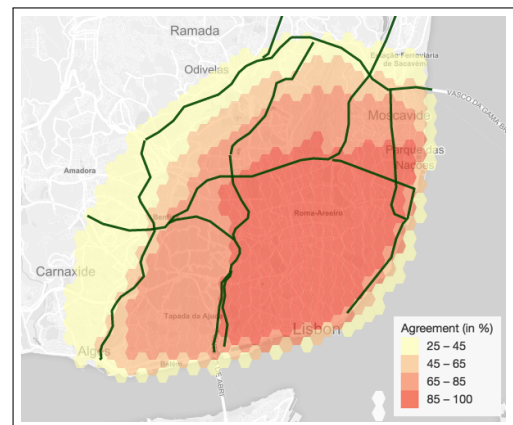
4.2.4 Official area of Lisbon

While interesting, results from both previous steps only bring conclusions on how people use space, they don't state much about how people perceive it. For that, we must relate the answers to these steps with to those to where we ask people to draw what they think. We begin with what should have been the

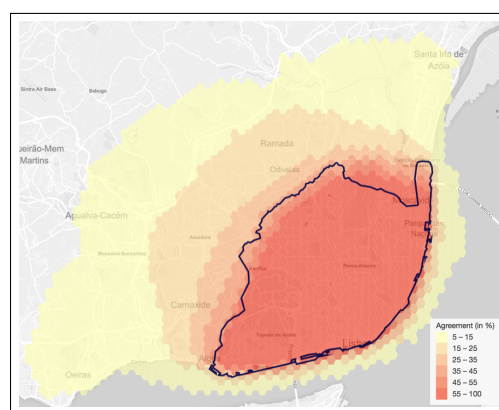
easiest to draw – Lisbon city limits. These limits are official, and can be seen on maps easily available to everyone, such as the subway network map. While we can say that, by looking at Figure 4.7(a), roughly half of the participants got the area almost right, there was also about **15% that drew only a much tinier version of the city**, bordered by the valley of Alcântara to the west, and by “2ª circular” and the airport to the north. This points to an interesting situation: the **borders seem to coincide with high speed roads**, see Figure 4.7(b). The smaller city version, in red, seems to be almost perfectly bounded by a first ring of such roads (Parque das Nações in the north-eastern part again being the exception), while the two orange-colored areas seem to fit nicely into a freeway in the west and another in the north-east. It is particularly interesting to note that the north-eastern bound, where the agreement drops below 45%, goes beyond official boundaries, and instead only stops when it reaches the freeway near it. We can trace back this behavior to previous, related work [Annechino and Cheng, 2011] where freeways are pointed as a barrier to one’s mental map, dividing the city and calling for a different perception between those parts. Once again, we identify the **existence of a more central Lisbon**, so strong in some people’s minds that it leads them to think of the city’s official area as being much smaller.



(a) Agreement on Lisbon boundaries, with the official boundaries layered on top.



(b) Agreement on Lisbon boundaries, with high-speed roads layered on top.

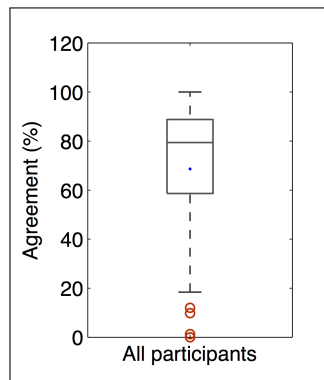


(c) Agreement on Lisbon boundaries with a lower threshold of agreement. Official boundaries layered on top.

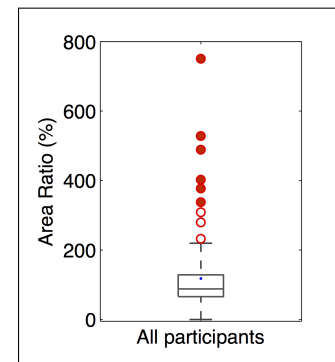
Figure 4.7: Agreement on Lisbon boundaries.

It is also worth noting that at least 5% of participants considered Lisbon as being much bigger than it actually is, including surrounding cities and suburban areas as part of it, see Figure 4.7(c), and given that

we did not provide the possibility of panning the map, conceivably there could have been even bigger drawings. We suspected that among these participants would probably be the ones who placed their living area outside of Lisbon but, at the same time, stated they live in it. However, after we exported the results relating distance between living place and area, and relative size of the drawn area, we found no correlation between those who were living outside of Lisbon and the size of the areas they drew. In fact, of the **20 people that drew an area at least 20% bigger than the official, only 8 lived outside the official boundaries.**



(a) Variation on the drawn areas agreement with the official area of Lisbon.



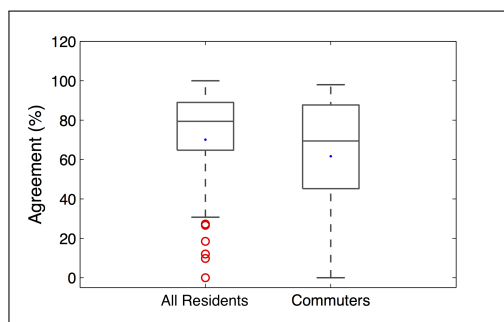
(b) Variation on the size of drawn areas relative to the official area of Lisbon

Figure 4.8: Box plots for drawn areas by all participants

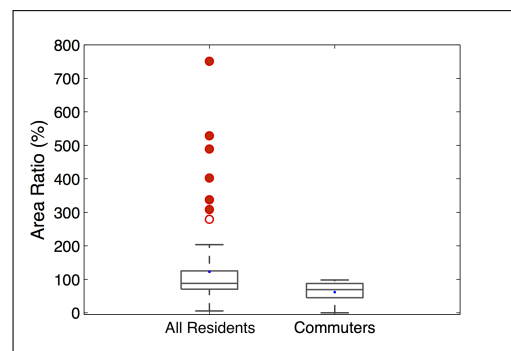
Looking to better quantify the perception of the participants, we found the agreement between each one's drawn area and the official area of Lisbon, plotting them into a box plot graph, see Figure 4.8(a). As you can see indicated by the blue dot inside the box, the mean agreement was around 70% of the area, and although there were some low values, more than 75% of them were above the 60% agreement mark, while 50% of participations exceeded 80% of agreement with the official area. Furthermore, there were 8 participations with close to, or exactly, 100% of agreement, something that reminded us that it would be easy to attain full agreement if the drawn area contained all of the official area, and looking at Figure 4.7(c), we know that some people did exactly that. To tackle this, we also box-plotted the ratio between the size of the two areas (drawn area relative to the official), and it shows that more than 50% of participants drew an area greater than the official one, as the above map pointed to. This data points to the **general tendency of over-sizing the area of Lisbon**, thus revealing one more type of inaccuracy to account for.

We previously saw that the most meaningful places seem to be influenced by the kind of relation one has with the city. It's thus rational to see if the same applies to how a person perceives space, and in this case, the boundaries of the city. For this step, we identified two general groups: the ones living in Lisbon, which include both "residents" and "immigrants"; and the ones only working or studying in Lisbon, the same "commuters" as before. To analyze the results, we again made use of box plots, Figure 4.9. As we can see by the graph that addresses the agreement for both groups, Figure 4.9(a), and as expected, people living in Lisbon seem to be more correct overall, when comparing to the commuters, even considering some outliers. However, as we look into the size of the area participants drew, Figure

4.9(b), we notice that people living in Lisbon drew, in general, much bigger areas than commuters, averaging around 120% against 80%. This plays in favor of residents and immigrants, since that with such big areas, it's much less likely to miss. The interesting point, though, is the difference in behavior among these two groups, since **commuters tended to under-size the area of Lisbon, while residents and immigrants did the opposite**. We suspect that such behavior derives from where each of the participants live. A person who lives on the surroundings of the city area, and is aware of living outside of it, passing the city borders twice a day most of the days, probably has a better understanding of where the actual city of Lisbon begins, while the individual who lives in Lisbon, more easily has a less defined notion of where the city ends and adjacent cities begin.



(a) Variation on the drawn areas agreement with the official area of Lisbon.



(b) Variation on the size of drawn areas relative to the official area of Lisbon.

Figure 4.9: Box plots for drawn areas by Residents and Immigrants, versus Commuters

Having analyzed the results by splitting the participants by their relation with the city, we saw how that same relation can affect one's perception. However, we also wanted to test the influence of time in space perception. To do this, we gathered both immigrants and commuters together³, as we can classify them by how long they know Lisbon, and then split them into two categories: long-term, and short-term. We distinguish between those two categories using the limit of 5 years, which matches the normal conclusion time of a college degree and seemed relevant to apply for our particular population demographics. As observable by the graph in Figure 4.10, the long-term participants have a better understanding of the limits of Lisbon, as they average about 75% of agreement, versus the 60% of the short-term kind, a value which almost 75% of the first kind surpassed. This leaves us with the conclusion that the **level of experience with a certain space, in this case measured with how long a person knows that space, has a significant influence in its perception**.

Finally, and as pointed by several studies discussed in Chapter 2, the type of transport people use can have a major impact on their mental map, which led us to test it on our results. As we asked every participant for the types of transport they used most to get around, we needed only to split them by the answers to that question.

We formed several groups: one for car users, another for public transport users, another for “walkers”, and a last one for “non-walkers”. The results, however, reveal no large enough difference to be pointed, which goes against most of previous works analyzed in Chapter 2. We blame this to the fact that

³Note that only 1 emigrant and 2 tourists reached these steps, which led us to keep them out of future analysis

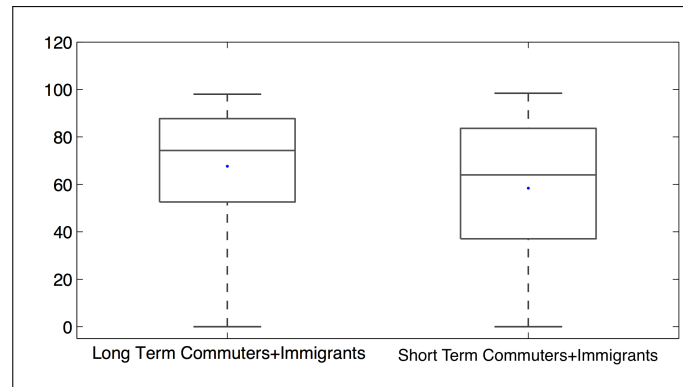


Figure 4.10: Drawn areas agreement and area distribution, by long-term, and short-term, commuters and immigrants.

both public transports and walking are too short-ranged to influence the perception of such a large area. Besides, the analyzed studies didn't address the influence on boundary perception, but rather referenced the type of transport as influence to how one sees the closeness between two points, or to how one perceives the surrounding area to a station compared to one further away from it, etc. We thus take away the conclusion that **for such large areas, and in what regards boundaries perception, the type of transport people regularly uses does not have a significant influence in their mental maps.**

4.2.5 Neighborhoods' mental maps

Looking back, the type of results analyzed so far, though enlightening and interesting, do not specifically show a mental map. As we asked for participants to draw official boundaries, we mostly ended up with participants' mental image of Lisbon borders, not of what, for them, is the "real" Lisbon and what is not. We tried to make up for this with the "Draw your Lisbon" step, analyzed in Section 4.2.3, and as already seen it provided us a good view over what the important and meaningful part of Lisbon is, but it still doesn't show a true, unbounded mental map, one that shows how a group of people actually imagine a space.

By creating the last step for neighborhoods drawing, even though we don't end up with a mental map of the city, we can observe true mental maps through the results for areas which aren't officially defined or bounded, also finding inaccuracies in those who are. Like so, considering there were 48 neighborhoods to choose from, we decided to only focus on neighborhoods that showed interesting results and fulfilled at least one of these points: they have no official area; they share their name with a subway station; they have official boundaries but results show a great discrepancy, or interesting agreement; they especially address a certain sub-group of participants (e.g. areas with bars for young people).

Non-bounded areas

We first look into non-bounded areas, and a quite peculiar case for the city under scrutiny. In Lisbon's historical center, several zones can be identified by anyone familiar with the city, from where we point

Baixa, Chiado, Bairro Alto, and Rossio as among the most relevant. And although their great popularity and history, they are not properly bounded, and can differ completely from each person. As we can see from Figure 4.11(a), the results concerning the area of Baixa show a general consensus around a particular group of blocks, characterized by its planned streets and typical architecture, called Baixa Pombalina. However, as that area ends, so does the consensus. Even considering only the orange-shaded areas, the adjacent zone to the west seems to be of relevant interest, as agreement diverges and varies between relevant values of 30 and 70%. Even more interesting, is the fact that another neighborhood, Chiado, in Figure 4.11(b), has most of its area inside that western-part of Baixa, if considering values of at least 30% of agreement. It goes to show just how interesting the results for these two neighborhoods are, since they are **both identified as different, separate areas, but at the same time viewed as being part of one another**.

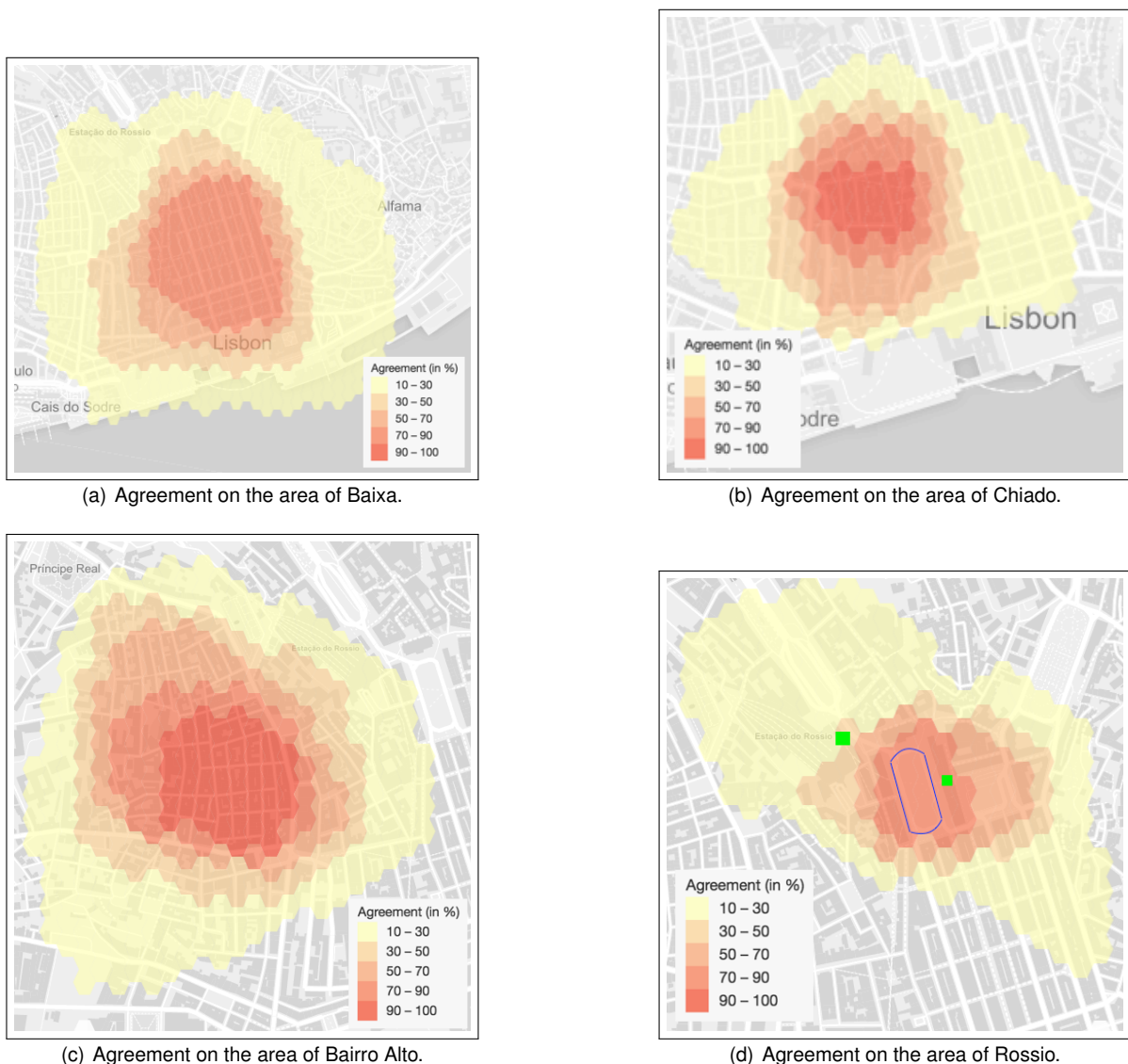


Figure 4.11: Agreement on Lisbon's historic areas.

Bairro Alto, Figure 4.11(c), presents an interesting case of disagreement, as a relevant share of people included a relatively large area on their drawings, compared with the zone of most agreement.

We can then identify a **clear core of small blocks**, followed by a larger area that seems **bounded by larger, specific streets**, particularly to the south, but also noticeable on the north-eastern slope of the darker orange-shaded extent.

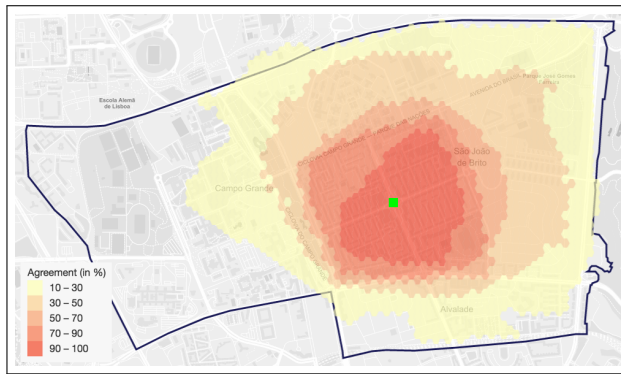
Rossio, in Figure 4.11(d), is generally associated with a specific square, officially named Praça Dom Pedro IV, but is a name popular enough that it was the one chosen for both the train and subway station nearby. However, how big is Rossio? Is it only the square? Or does it extent to, and further beyond, the train station? As the figure shows, there is a clear concentration around the square, there drawn in blue, but the adjacent plaza to the east, Praça da Figueira, draws at least 50% of agreement, and although we can't be sure, we suspect that the subway station, eastern green square, influenced those decisions. The same phenomenon seems to happen with the train station too, northern green square, and its adjacent patio to the south. These results prove how important the **combination of public, open spaces, with important transit hubs, can influence the mental map of a population**.

Officially-bounded areas

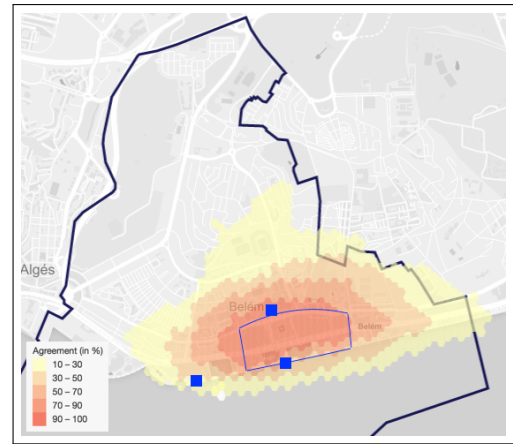
The previous set of neighborhoods reveals how the population's perception can vary when confronted with non-bounded areas. They find their own, personal boundaries, be it changes in architecture, or street planning, for the Baixa/Chiado areas, larger streets, for Bairro Alto, or the limits of an open and public space, for Rossio. Considering how different each one's opinion and thoughts can be, it's quite interesting to find close to general agreement on some borders. But what if we compare mental maps with official boundaries? Did authorities make a good job on defining administrative areas according to how people imagine them to be? We target just that by comparing what people drew for an area with the same name of official administrative districts.

In Figure 4.12, we can see four different parishes, or "freguesias", with their boundaries laid out on top of the results. These were among the most drawn areas, and represent a good overview over most possible cases. Figure 4.12(a) shows the parish of Alvalade and how participants perceive its area. We can see a clear agreement over what it's known as the neighborhood of Alvalade, a mostly residential urbanization project from the middle of the 20th century. While the darkest shades avoid some parts of the said urbanization, the following lighter, orange shades fill the rest of it, forming an almost perfect square on the map. Furthermore, there seems to be more disagreement, mainly regarding the eastern borders where each shade covers more area. Regardless of how we consider the results, though, it's clear that the official parish is of much greater area than what was drawn, **reaching zones for which is safe to say no participant would feel in Alvalade**. The same seems to happen with Arroios, Figure 4.12(c), where there is a much greater space, relatively speaking, left blank. As we can see, most drawings are concentrated around the exits of the subway station with the same name, green squares on the map, forming a circle on the surrounding area with little disagreement.

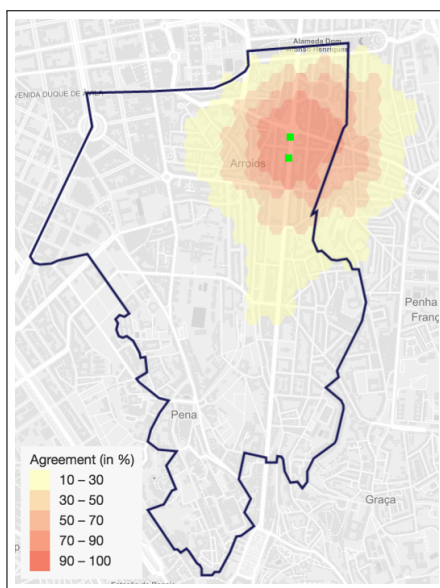
Parque das Nações, Figure 4.12(d), is probably where there is more agreement over the official areas. Participants included most of the riverside walk and park, and seemed only to disagree over where it ended. The majority reached the latitude of Moscavide, another neighborhood, and stopped drawing there, while others continued until they had reached Vasco da Gama bridge. What's interesting



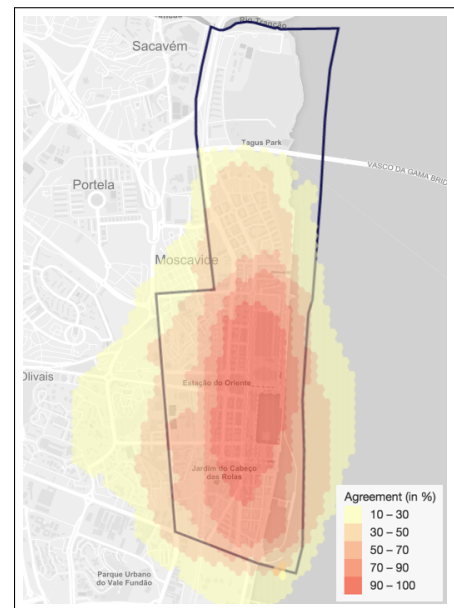
(a) Agreement on the area of Alvalade.



(b) Agreement on the area of Belém.



(c) Agreement on the area of Arroios.



(d) Agreement on the area of Parque das Nações.

Figure 4.12: Agreement on some of Lisbon's officially bounded parishes.

is that none of them continued past that bridge, even though the same park continues past it, showing how participants probably **take the bridge as a border for the parish, or even for the city**.

Belém, Figure 4.12(b), follows the pattern of the first two neighborhoods, where participants left a great area of the district untouched. This area is internationally known for its riverside monuments (marked with blue squares on the map), its different museums, and, for locals, various public parks and gardens (delimited with the thin blue line on the map). It's clear that the general orientation was based on exactly those points, since the area of most agreement matches the gardens and surrounding museums. There seems to be not much discussion over how north that area goes, and rather the disagreement is most found longitudinally for both west and east. Regardless, participants stayed away from the northern part of the district, where the old and small buildings, and large monuments, give place to, mostly, single family residences for the higher class.

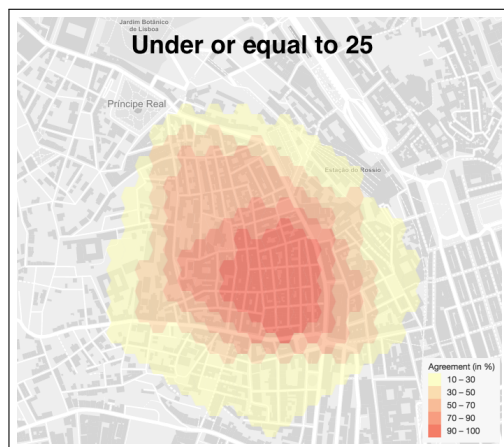
Once again, this points to the same group of influences to someone's mental map: **public trans-**

portation habits; physical barriers such as larger and busier streets or bridges; public spaces and monuments; or drastic change in architecture.

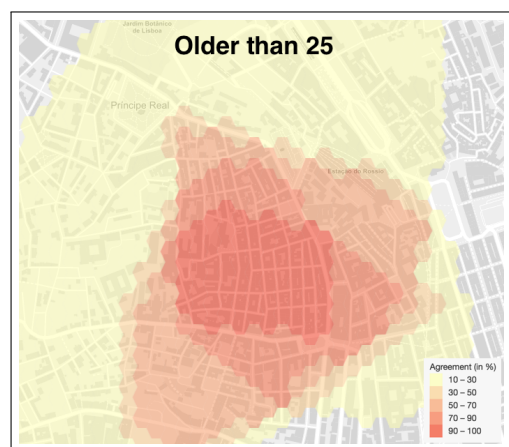
Areas by subgroups of people

In order to find even more influencing factors, we wanted to find out how the drawings vary with each person's characteristics. On our case study there are some areas that show just that: some that are almost exclusively known for a type of activity, others characterized by their touristic appraisal, and other known only as residential neighborhoods.

Bairro Alto is mostly known for its nightlife, and the way it attracts mostly young people to its many bars every week. Based on that fame, we analyzed the differences in perception between younger people, under 25 years, and older people. The results share a basic core, as you can see in Figure 4.13, but other than that, they are quite different. By following the orange extent, we notice that older participants, Figure 4.13(b) spread their drawings much more than the younger participants, following no clear boundaries. It is important to note that younger participants concentrated their drawings over a more bar-filled area, while the older group also reached more touristic places, and shopping areas. This makes it clear of how **influenced someone's mental map can be by the use that same person has for it.**



(a) Agreement on the area of Bairro Alto, according to participants under 26.

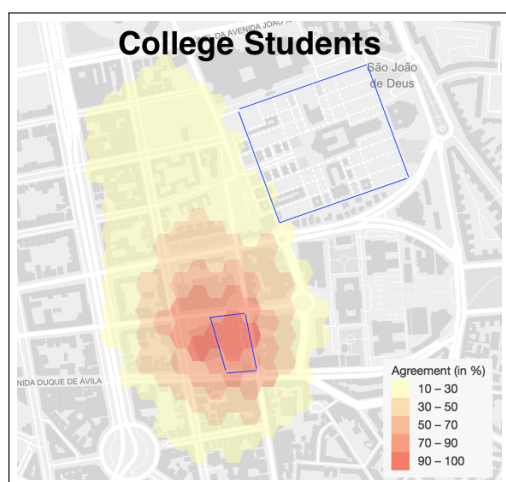


(b) Agreement on the area of Bairro Alto, according to participants over 25.

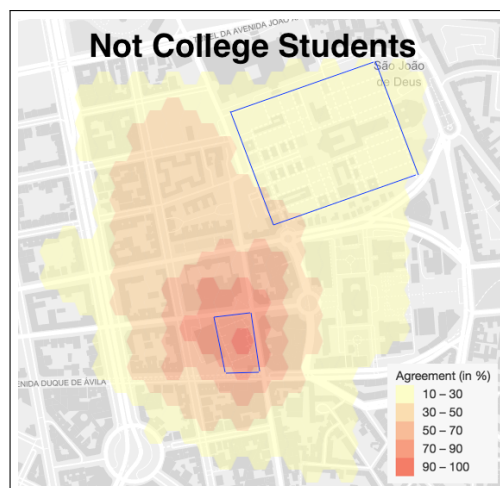
Figure 4.13: Comparison of the agreement on Bairro Alto, among different age groups.

Another great case study for this kind of analysis is Arco do Cego, an area near the college most participants are from. While there is a whole, clearly delimited neighborhood with that name, there is also a park with the same name where lots of college students gather to have a drink after classes. It's thus obvious the choice to split the participants into two groups, one representing students from the nearby college, and another for the rest of participants. We achieved this by filtering participations that placed a meaningful place marker inside the college campus, probably reaching most of the targeted group.

As we can see from the results, Figure 4.14(a), college students' drawings concentrate more around the park, blue delimited area to the south, a zone with which they are probably quite familiar, while a



(a) Agreement on the area of Bairro Alto, according to participants that study in the nearby college.



(b) Agreement on the area of Arco do Cego, according to participants that don't study in the nearby college.

Figure 4.14: Comparison of the agreement on Arco do Cego, among students and non-students.

greater number of non-college students, Figure 4.14(b), tended to include surrounding areas, as we can see from a greater orange shaded area, and some even took the care to consider the neighborhood that takes the same name, in blue at the northern end of the map.

There are two things to point out, then: how most people ignored the neighborhood, and the influence of familiarity with the space. They thus show us how surprising a mental map can be, **ignoring places that would be normal to include in official maps as part of some delimitation, and how the familiarity is taken into account, rather than just a name.**

4.2.6 Case study conclusions

We conclude our study by, first of all, pointing how unfortunate it was for not collecting more diversified answers, notably the lack of tourists, a group that could have had so much more insights. Nevertheless, we were able still to testify on the first-hand the power of habits, age, or just simply life itself, in regards to how they can shape one's spatial orientation and image.

Not only did our tool was able to prove the findings of many previous projects on the subject of mental maps, thanks to it we could actually see how such maps were formed and shaped. It was possible to freely explore the influences behind each drawing, and compare visually and statistically the results from any group that we saw fit.

We proudly show the effectiveness of our tool compared with the one used by the project that originally inspired this study, "Crowdsourced neighborhood boundaries", described in Section 2.2.1, not only offering us "crowdsourced boundaries", but also critical information behind each of those boundaries.

We can thus say that our framework not only helps, just as effectively as other techniques, to create and analyze a detailed survey on a population's mental map, it also does it in a much faster and more flexible manner.

Chapter 5

Evaluation

As stated at the beginning of this dissertation, we wanted to evaluate the effectiveness of our framework, which in turn can be described by the success of its two parts: the survey, or data gathering tool, and the analysis tool. Each of those parts has its different goals, and thus, different factors to evaluate.

The framework could be tested with extensive user tests, focused on usability measurements. However, due to the extension of our project, we weren't able to perform user tests with enough people to have statistically relevant value. Nevertheless, we carried two sets of **formative tests** that showed some flaws with our project and deserve to be mentioned in its evaluation.

Formative tests to the survey interface included 6 people, with ages from 19 to 25, all college students. They revealed an overall difficulty on all phases with interactions with maps, but especially in phases where users had to draw boundaries on the map. Users would never read the provided instructions and would try to act on their own whenever they faced a problem. This, consequently, would cause more serious problems and a greater feeling of frustration. We thus identified the special need to prepare the interface to deal with errors, and minimize their consequences, in order to control a chain of frustrations that could ruin the experience.

The tests carried on the data analysis tool, on the other hand, showed less crucial errors, but a greater difficulty in the overall comprehension of the interface and its features. They counted with 5 people, from ages between 20 and 48 years, all with high school completion or higher. Although most achieved a generally good result, major problems were found with the filtering feature. Every person had difficulties identifying the correct filter to load, and knowing what data it should be applied to. Furthermore, and more importantly, they greatly struggled with understanding the "Filter Group" feature, that allowed combination of filters with varying logic, as described in Section 3.5.7. These tests thus helped us identify the need to refine the filtering feature, with more available help such as tool-tips, and with clearer and more comprehensible names for each action and element.

Regardless of the results in formative tests, though, we can only evaluate the true success of the framework by applying it to a real world case, and see if it fulfills the original goal, in this case, of gathering, and analyzing mental maps.

5.1 Evaluating the Data Gathering Tool

The success of the data gathering tool is mainly influenced by the usability of the survey interface. In its turn, in addition to user tests, the interface can easily be evaluated simply by the amount of quitters among participations of a survey, provided there is a big enough number of participations. This is due to the fact that, when protected by anonymity, and having no particular interest in the survey, users will very easily quit at the minimum difficulty.

Since the survey created for our case study included every type of interaction originally offered by our framework, it's a good test to the usability of each of them and to the survey interface in general.

That being said, we looked into the variation in participations along the crucial steps that each participant went through on this survey, as we did in Section 4.2. That variation can be seen in Figure 5.1.

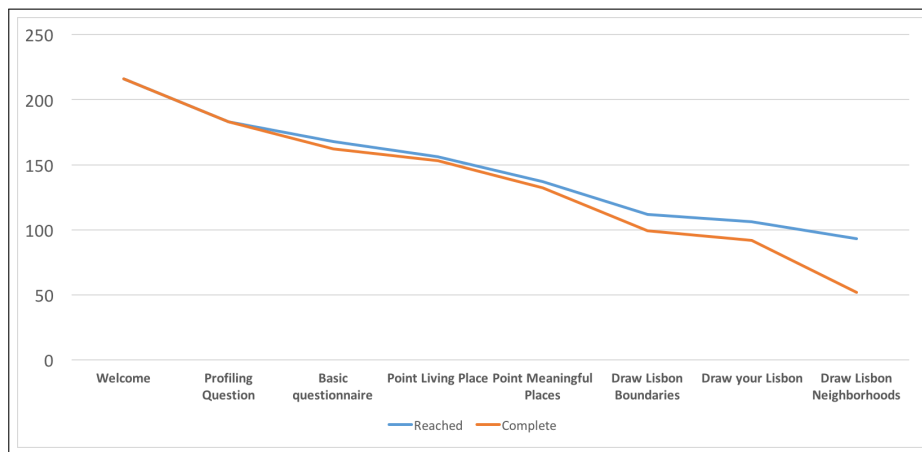


Figure 5.1: Variation of participants that reached the different phases and completed them.

If we focus on the steps of the survey in which users were confronted with new forms of interactions – from the third to the fourth, and from the fifth to the sixth – it's possible to have a general view of where users had more difficulties.

Thus, we can identify the “draw area” interaction as being the most challenging, as we analyze the drop from around 140 participants that completed the “Point Meaningful Places” step, to the under 100 participants that completed the next. Comparing with the drop of only around 10 participations from “Basic Questionnaire” to “Point Living Place”.

The results from the previously mentioned formative tests, can help explain this phenomenon, as all 6 of the test subjects struggled with the same type of phases. The majority of the problems surged when they wanted to do something else than draw an area, such as editing its shape or panning the map after drawing the area. Their natural reaction involved further interactions with the map, instead of resorting to the sidebar, as they should have done (see Section 3.4.3). The sidebar not only contained the buttons to use, but also contained a series of instructions that covered the problems they were having.

Joining both these insights, and although a set of only 6 tests can't prove anything, we suspect that many participants faced the same problems as those that were tested, if not on the first “draw area” step, maybe on the second or third, as the drop in participations keeps growing from one to the next.

Nevertheless, since around 33% of participants completed the survey in its entirety, coupled with the great level of complexity that our survey had by having 3 steps with a “draw area” interaction, show that the tool reached a very reasonable level of effectiveness, by gathering a relatively large amount of data.

5.2 Evaluating the Data Analysis Tool

The data analysis tool presents a more challenging case for evaluation. User tests or formative tests don't fully replicate real world use of the application, since people in the tests don't necessarily know about the due concepts of how Semantic Cities surveys are structured, or what the survey under analysis consists of. Researchers that use this tool with their own created surveys, though, would have most of the needed knowledge to help them navigate through the complex interface. Furthermore, researchers would be willing to fight against some usability struggles that uninterested testers would promptly give up on.

As such, we evaluate the data analysis tool mainly for the effectiveness of results it can produce, more than the performance measured on user tests.

Regarding the produced results, then, the application leaves a good impression, since we were able to derive a wide variety of conclusions from it when we applied it to our case study, see Section 4.2. Furthermore, it was also able to corroborate observations made in related projects that resorted to non-digital approaches which represented the best available option, see Chapter 2. This shows how decisive can be this tool, letting researchers reach the same conclusions but through a much more efficient approach.

Nevertheless we took into account the different insights identified by the tests, and realized that, for the most logic-heavy tasks, the interface has a learning curve that can be too problematic. Uncovering the full power and all the possible configurations present in the interface can take a while. On the other hand, as soon as those problematic features were explored by the tester, there were rare cases of repetitive errors. This points to the need of localized help for most actions present on the interface: elements like floating tips, and clues spread across the interface that better indicate what each thing can do.

5.3 Discussion

Both the tests and the results of the case study point for an overall successful implementation of the framework.

The survey interface has few things to improve, requiring only special focus on better dealing with user errors on phases that include interactions with maps.

The data analysis tool, on the other hand, revealed itself as being very effective, but not that efficient. It requires some brave exploration for using its most powerful features, increasing the chance of a frustrating experience. Still, note that the tests also registered very positive results in the overall navigation and error rate, leaving only the challenge of mitigating the learning curve.

Regardless of all those observations, we can still say that we achieved our main objective, initially specified in Section 1.1, of “creating a set of digital tools that, together, provide a complete and customizable framework for finding a population’s mental maps towards any area”, as clearly proved by the complete and insightful case study we made, and as shown by the overall easy adaptability of the subjects to both interfaces in our tests.

Chapter 6

Conclusions

Mental mapping can be a very useful tool in predicting behaviors and identifying ideas that people share with a certain space. Areas like urban planning and psychology can greatly benefit from studies relying on mental maps.

However, as we've introduced in this document, even considering recent solutions, there are currently no clear better options to execute those studies than the hard process of gathering sketches and making long personal interviews, and then comparing them by naked eye, with their highly variable results.

We thus identified the need to develop a solution that could easily replace that method, by implementing a completely digital framework to both create a survey on mental maps, and analyze its results.

We analyzed several studies on space psychology to find what was the best way to uncover a mental map, and what influenced their shape the most.

By also targeting previous creative solutions to this problem, and comparing them with classic methods, we were able to understand what crucial points they had missed on their implementation.

Gathering both insights together, we were able to come up with small list of crucial interactions that would make an impersonal and online survey as effective as personal interviews.

We decided to describe the surveys our framework would generate as a sequence of those interactions, and created a JSON object standard to specify each of them, taking the role of independent building blocks of the survey.

As we did to the survey specification, we created a pre-defined way to describe the input generated by a respondent, thus allowing the later analysis by a separate interface, directed to researchers.

Since we identified the exploration of subgroups of mental maps as a crucial factor to any study on the topic, we made sure to provide the possibility of extensively filtering the gathered data, and thus allowing researchers to uncover unique observations.

In Section 4.2, we put the analysis tool to test using a case study of the city of Lisbon. We found it was able to perform as planned, providing results as insightful as those from studies that followed classic approaches.

We further analyzed the framework effectiveness in Chapter 5, where despite some usability flaws, revealed that its both parts are solid applications.

Finally, we can say that we achieved our main goal of **creating a set of digital tools that, together, provide a complete and customizable framework for finding a population’s mental maps towards any area**, while also fulfilling the secondary objective of **finding the different mental maps of Lisbon**

6.1 Future Work

Regardless of the achieved results, our framework can still be further improved. We identify the most crucial points as being:

- Survey creation tool: As described in Section 3.3, it would be very useful to offer researchers a more friendly way to create a survey than writing a JSON file. One more separate interface should be developed allowing the design of a survey, while still allowing the same flexibility provided by the current solution.
- More error-friendly drawings over the maps: As presented in Chapter 5, the part of the survey interface concerning drawing on the map should allow errors to be made while mitigating their consequences. For example, by providing an clearly visible “undo” action.
- More configuration options over the survey: There could be even more properties to include in each type of phase in the survey. These include, but are not limited to: more follow-up options, such as a link to a twitter profile; more time units in the “time-input” answers; support for answering with full dates to questions on questionnaires
- Localized help across the data analysis tool: To offer a better exploration of the great number of features offered by data analysis tool, we propose the creation of multiple tooltips, explaining what each element in the interface can do.
- “Frequently Asked Questions” for the data analysis tool: In order to better guide, right from the start, researchers in their analysis, we propose the creation of a list of guidelines or FAQ. By reading it, researchers should be introduced to the different powerful tasks they can execute in the tool.
- More clear filter system: Since it was one of the more difficult to comprehend features, we propose a revision of the filter system on the data analysis tool, more specifically, a more clear naming and obvious roles of each element
- Easily identify and filter corrupt data: As experienced by ourselves, there can be corrupted data in the results of the survey. It should be possible to identify it as researcher analyze the results, and easily filter it whenever appropriate.

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Appendix A

Semantic Cities JSON Specification

Each survey phase is described as a JSON object, with a `type` property. This property can have the following values:

- `questionnaire` for a questionnaire phase
- `survey-information` for a phase that's only for displaying information to the participant
- `point-a-place` for a phase where participants can place a single marker on a map
- `point-multiple-places` for a phase where participants can place multiple markers on a map
- `draw-area` for a phase where participants can draw one or more polygons on top of the map, representing a certain area
- `draw-multiple-areas` for a phase where participants can choose, among a list of areas, one or more to draw

The `type` property is the only one common to every phase. Besides that, each phase type has their own properties and the code that uses them should take their specification into account.

```
[
  { //phase number 0
    "type" : "phaseType",
    //phase-specific properties...
  },
  { //phase number 1
    "type" : "somePhaseType",
    //phase-specific properties...
  },
  //other phase
]
```

(a) Survey's JSON general structure

```
[
  {
    //input on phase number 0
  },
  {
    //input on phase number 1
  }
]
```

(b) General structure of the JSON for the input on the survey

Figure A.1: General structures for both data objects.

In addition to a JSON specification for describing a survey, we also needed to create a standardized JSON representing a participant's input on the survey. We followed a similar approach, breaking it into

one object per phase, each representing the input on the phase with same index on the array, as you can see when comparing Figure A.1(a) with A.1(b). We decided to maintain a simple structure on the input array, opting for leaving out information of the phase that originated it, and dropping the `type` property. Instead, we bind the input on each phase to the originating phase only by the index on the input array. This makes it so that the input JSON can't be analyzed without access to the survey JSON, as the first depends on the second for its content to have any meaning. We will analyze this later, as we delve into the specification for each phase type, and the input it originates.

A.1 Phases of type “questionnaire”

Phases of `questionnaire` type are among the most complex to specify, for their arbitrary number of questions. In order to support this feature of having as many questions of any type in each questionnaire phase, the JSON for a `questionnaire` type of phase must contain a `questions` property described by an array, where each element is an object representing a question, see Figure A.2(a).

The specification of the input object produced when interacting with a `questionnaire` phase is similar, but instead of a `questions` array, it has a `answers` property. It consists of an array, where each of its elements is an object representing an answer to a question, and follows a structure specific to the type of answer that question offers.

```
{
  "type" : "questionnaire",
  "questions" : [
    {
      //question specification
    },
    {
      //other question specification
    }
  ]
}
```

(a) “questionnaire” phase’s top-level specification

```
{
  "questionBody" : "How old are you?",
  "answer" : {
    "typeOfAnswer" : "number-input",
    //...
  }
}
```

(b) “questionnaire” phase’s “questions” common specification

Figure A.2: General specification for “questionnaire” phases.

The specification for each question follows a common structure, starting with the `questionBody` property, the question to ask, and an `answer` object, containing the properties of the answer to give. The later is specified by a `typeOfAnswer` property and the properties that are specific to that answer type, see Figure A.2(b). Answers types range from:

- `number-input` for answering with a number
- `time-input` for answering with a time period, such as “10 years”
- `month-input` for answering with an approximate date, with only month and year, such as “03.1984”
- `choose-multiple` for answering with multiple items (check boxes) among a list of items
- `choose-one` for answering with only one item among a list of items

- select-dropdown for answering with a selected item among a dropdown with a list of items

Each of those types has its own object specification in a questionnaire phase and they can be consulted on Figure A.3. For the input produced by each of them, see Figure A.4. We detail each of the specifications bellow.



Figure A.3: Specification of the different answer types.

As you can see in Figure A.3(a), the number-input answers have a minimum valid value, a maximum valid value, and a supportText property that specifies a text string to help giving the input a little more meaning. Note, however, that all these three properties are optional and for usability purposes only. One could add a number-input type of answer just by specifying the type property.

By answering this type of answer, the participant produces a simple input object with a number property, with a number value, representing the number the user introduced on the interface.

The specification for a time-input answer type, Figure A.3(b), along with optional minimum and maximum values, must have a timeUnits property. This property consists of an array, where each of its elements is a string representing a time unit, among "Years", "Months", or "Days". One could opt to include whichever unit of those three, in whichever order. However, only those three options are compatible with our framework, and more options, like "Hours", are planned for future improvement. This answer produces an object with a number property, specifying the number introduced on the interface's duly field, and a timeUnit property, a string with the value of the time unit the participant chose when

```

{ //input on a questionnaire phase
  "answers" : [
    { //`number-input` answer
      "number" : 18
    },
    { //`time-unit` answer
      "number" : 5,
      "timeUnit" : "Years"
    },
    { //`month-input` answer
      "month" : 10,
      "year" : 2016
    }
  ]
}

```

(a) Input produced by answers of type "number-input", "time-input", and "month-input"

```

{ //input on a questionnaire phase
  "answers" : [
    { //`choose-multiple` answer
      "checks" : {
        0 : false,
        1 : true,
        2 : false
      }
    },
    { //`choose-one` answer
      "index" : 0
    },
    { //`select-dropdown` answer
      "selected" : "America"
    }
  ]
}

```

(b) Input produced by answers of type "choose-multiple", "choose-one", and "select-dropdown"

Figure A.4: Specification of the input produced by the different types of answers.

answering the question (ranging between "Years", "Months", or "Days").

Answers of type `month-input` have the most simple specification, Figure A.3(c), as only the `type` property must be given. The interface must consider limitations associated with the type of this answer, for example making sure to only allow a maximum value of 12 for the "months" field. Its corresponding input object consists of two properties, `month` and `year`, each with a number a value, specifying what the participant introduced as month and year, respectively.

The specification for `choose-multiple`, Figure A.3(d), and `choose-one`, Figure A.3(e), share some similarities, as both have the property `answerOptions`, an array of objects, each specifying an option the participant can choose from. Also, on both cases, the objects for each option share the property `answerBody`, a string which specifies the text to display for that option. In addition to these properties, for `choose-one` answers, the object for each option can have a `effect` property, an array of integers, where each specifies a phase number on the array of survey phases. This is crucial for a more complex survey, as it changes the route of some participants depending on their answers. The numbers are added to a queue of phases, representing the next phases the participant will go through.

The input produced by each of the previous two types of answer is not so similar, though. Since a `choose-multiple` answer can have multiple selected options, we opted to represent its input with a `checks` property, which in turn is an object with one property for each option. Each of those properties, with its name equal to the option index, can have either a "true" or "false" boolean as its value, representing a selected or unselected option, respectively. As for a `choose-one` answer, since only one option can be chosen, we implemented a simpler solution, representing its input with a `index` property with a number value, equal to the index of the selected option. If no option is chosen, then it never acquires any value, remaining `undefined`.

Finally, an answer of type `select-dropdown`, see Figure A.3(f), follows the same idea as the previous two types in regards to the available options, only changing some properties names to `selectOptions` and to `optionBody`. However, it adds one more property to the mix, `answerPrompt`, describing the text

to show on the dropdown box when no option is selected yet. This kind of answer produces a simple input object, with only one property, `selected`, which takes the value, as string, of the selected option.

A questionnaire phase is thus specified using any number of these question objects, of any type, offering great flexibility and power to the survey designer.

A.2 Phases of type “survey-information”

Phases of type `survey-information` are simple briefing or debriefing steps in the survey. As so, one of the only needs of its corresponding descriptive object is a property for the title and the body, specified respectively by the properties `title` and `description`. The first is a simple text string, while the second, considering that such a step could need a high volume of text, is an array with each element representing a paragraph of the text to display. In Figure A.5 there are two examples of possible `survey-information` phases.

```
{
  "type" : "survey-information",
  "title" : "Welcome to the survey!",
  "description" : [
    "This a survey on dogs.",
    "It lasts for about 15 minutes.",
    "Here's one more paragraph!"
  ],
  "nextSteps" : [1, 2, 3]
}
```

(a) Specification of a “survey-information” phase. Example for a briefing step.

```
{
  "type" : "survey-information",
  "title" : "Goodbye!",
  "description" : [
    "Keep up with the results..."
  ],
  "followup" : {
    "email" : "Provide your email"
  }
}
```

(b) Specification of a “survey-information” phase. Example for a debriefing step, with a follow-up option.

Figure A.5: Specification of a “survey-information” phase.

The first of those objects, Figure A.5(a), tries to illustrate a welcome page where basic information about the survey is given, such as its purpose and expected duration. There, in addition to the `title` and `description` properties, it's introduced one more crucial attribute, `nextSteps`. It specifies an array of phases numbers to be added to the queue of following phases, much like the `effect` property of `choose-one` answers that we described in Section A.1. We found the need for this as we observed there was no better way, following our planned architecture, to initialize the phases one participant would have to go through. We thus made it a **requirement to begin a Semantic Cities survey with a “survey-information” phase**, where a **“next-steps” array must be specified** in that same object. This decision, although limiting, didn't seem to be a big trade-off, since beginning a survey with a briefing phase should accommodate most designs.

The second example, Figure A.5(b), illustrates a debriefing step, or the last step of a survey. It introduces one more property, `followup`. It was created to offer a way for participants to be notified of the survey progress, like sending them a link for a blog post with the results, for example. We initially thought of many possibilities for the execution of the follow up, like a button to redirect to a Twitter profile, or Facebook page containing all the progress. However, we ended up settling for only one follow up channel, the e-mail, leaving other options for future work. In order to facilitate further implementation,

though, we still defined the `followup` specification as an object. Every type of follow up channels would be added as properties on that object, with their respective names, such as `twitter`, `facebook`, or `email`, and those with defined values would be displayed on the interface. Of course, for this first version, the interface only supports the `email` attribute, which value, a string, specifies a certain text to serve as introduction to the follow up. Thus, when faced with a phase with the due attributes, participants have the possibility of providing their e-mail, registering it with the rest of the saved participation on the database.

This type of phase, even when it doesn't have a defined `followup` property, produces an input object, too. If there's no `followup`, or if the user didn't fill it, then an empty object is submitted as the input on that phase, leaving the responsibility of dealing with it for the analysis web-app. When there's a `followup` or, more specifically, an `email` property and a respective field that the participant fills, then an `email` property is added to the input object, as you can see in Figure A.6.

```
{  
  //if no followup specified  
}  
  
{  
  "email" : "jobs@steve.com"  
}
```

Figure A.6: Different input objects produced by “survey-information” phases

Finally, note that a `survey-information` phase could have all of the presented properties on its specification, even though we don't see any obvious design where it would make much sense to add more steps to the survey and, at the same time, ask for the respondent to follow up on the analysis' progress.

A.3 Phases of type “point-a-place” and “point-multiple-places”

Phases of type `point-a-place`, and `point-multiple-places` share the same properties on their JSON specification, only differing on the value of the `type` attribute, as previously explained. This happens because these phases can share the same general interface: a map with which the participant interacts, and a place on the screen to display things like instructions and introductory text. The bulk of the work of treating each phase differently resides on the code of the data gathering web-app, which will be responsible to load the due interaction with the map depending on the type of the current phase. Note that this general interface applies to all phases with interaction over maps, and thus, resulting in similar specifications for all, as we will later detail.

A phase of one of these types, first of all, contains a property for its title and another for its detailed description, respectively specified by the properties `title` and `description`, both taking the same values as the same named properties described in Section A.2.

In addition to those two description-oriented attributes, it is also possible to include an `instructions`

property. While the reader may think that such thing can be included inside the `description` property, we thought it would be best to separate it, in order to render it in a specific manner on the interface. The `instructions` value is, like `description`'s, an array of strings, each representing a specific instruction. These instructions should include the basic interactions one can have with, in this case, the placed markers, but also anything the survey designers might think is relevant for the meaning they are giving to the target step.

```
{
  "type" : "point-a-place",
  "title" : "Place one marker",
  "description" : [
    "Show us your favorite bar.",
    "Point it on the map.",
    "Here's one more paragraph..."
  ],
  "instructions" : [
    "No. 1 - Don't try this on mobile",
    "No. 2 - Click on the marker to delete it"
  ],
  "mapView" : {
    //to setup the map
  },
  "markerRadius" : 250,
  "markerDetails" : {
    "color" : "#aa22dd",
    "fillColor" : "#23b",
    "fillOpacity" : 0.75
  }
}
```

(a) Top level specification of a “point-a-place” phase. Identical for “point-multiple-places”.

```
{
  //...
  "mapView" : {
    "view" : {
      "center" : [38.745247, -9.162425],
      "zoomLevel" : 13,
      "bounds" : {
        "northEast" : [38.925922, -9.416042],
        "southWest" : [38.558712, -8.945160]
      }
    },
    "tiles" : {
      "tilesUrl" : "https://mapbox.or.osm.link/",
      "tilesAttributes" : {
        "attribution" : "MIT license",
        "id" : "semantic.cities",
        "accessToken" : "gibberish",
        "maxZoom" : 16,
        "minZoom" : 12
      }
    }
  }
}
```

(b) Specification of the “mapView” property.

Figure A.7: Specification of a “point-a-place” phase. Identical for “point-multiple-places”.

As one can see in Figure A.7(a), the top-level properties of a phase with marker placement interaction include more than just descriptive and guiding properties. The most crucial, and the only required property in this kind of phase is what we called `mapView`. It was created to specify all of the things that Leaflet.JS, the map handling library we use in our framework, needs to render a map. As such, this property is represented as an object with two properties of its own: `view` and `tiles`.

The first is an object containing all the needed configuration for what concerns the view over the map. As Leaflet.JS initializes a map it takes a center, in geographic coordinates, and other options as arguments. Those other options include an initial zoom level and limits over the panning of the map. We supported these three factors by creating the `center`, `zoomLevel`, and `bounds` properties, which take in the same values as the Leaflet.JS function takes. Regarding the values of whatever includes geographic coordinates, we should note the particular way the map library represents them: as a bi-dimensional array with the latitude coordinate as its first position and the longitude coordinate as the second. Take Figure A.7(b) as an example for possible values.

The second property, `tiles`, regards another Leaflet.JS function, this time for initializing the map tile layer. A tile layer is basically the visual aspect of the map, and can vary from satellite, to abstract maps, and to other stranger visuals. All of Leaflet.JS-compatible tiles include a base URL that the library uses to fetch the tiles appropriate to the view over the map, and may or not include other options. The URL is a required argument for the initialization of the layer, and so it is specified separately from the options in the property `tilesUrl`. The survey designer should get the URL from the due sources, such

as OpenStreetMap¹ or Mapbox², making sure its compatible with Leaflet.JS. The `options` property is an object containing configuration options directly compatible with the ones accepted by Leaflet.JS. Note that properties such as `id` or `accessToken` properties in Figure A.7(b) are only required by some tiles resources, such as Mapbox, and if needed it should be specifically mentioned at the resource's website.

Finally, `point-a-place` and `point-multiple-places` phases offer the optional configuration of the markers' aspect, providing the `markerRadius` and `markerDetails` for it. The `markerRadius` should be specified as a number, representing the radius, in meters, of the markers that will be places. `markerDetails` is an object that is directly given as argument to the Leaflet.JS function that generates the marker. As such, its properties are the same as the ones supported by Leaflet.JS for its "Path" object³.

Both these phases generate similar input, producing a GeoJson object for a Feature Collection⁴ with as many Point geometry features as the markers placed on the map, see example in Figure A.8.

```
{
  "type" : "FeatureCollection",
  "features" : [
    {
      "type" : "Feature",
      "geometry" : {
        "type" : "Point",
        "coordinates" : [
          -9.162425,
          38.745247
        ]
      }
    },
    //... another Point Feature
  ]
}
```

Figure A.8: Input object generated by a "point-a-place" or "point-multiple-places" phase.

A.4 Phases of type "draw-area"

The specification of a phase of `draw-area` type is identical to the phases with marker placement interactions, described in Section A.3. The only difference relies on the marker configuration that, for these phases, doesn't exist. We then get a similar specification to one such as shown in Figure A.7(a), but without the last two properties.

Although the similarities when describing the phase, the generated input is completely different. Since the drawn areas are supported by the Leaflet.FreeDraw library, the generated input follows that library's own representation of the free-form polygons that the participant draws on these phases.

¹<https://www.openstreetmap.org> last visited on 07.10.2016

²<https://www.mapbox.com/> last visited on 07.10.2016

³<http://leafletjs.com/reference-1.0.0.html#path> last visited on 07/10/2016

⁴See FeatureCollection specification on <http://geojson.org/geojson-spec.html#feature-collection-objects> last visited on 07.07.2016

Leaflet.FreeDraw saves each generated polygon as an array where each element represents a vertex on that polygon. Each vertex is described as a bi-dimensional array with a first position for latitude coordinates and a second for longitude. An example of the produced array can be seen in Figure A.9. It's an array like this that is saved into the database as the input on the phase, as JSON directly supports arrays and thus brought no need to wrap it in an object.

```
[
  //polygons
  [
    //polygon 0
    [38.745247, -9.162425],
    [38.925922, -9.416042],
    [38.558712, -8.945160],
    [38.745247, -9.162425]
  ],
  [
    //polygon 1
    //vertices coordinates
  ]
]
```

Figure A.9: Input object generated by a “draw-area” phase.

A.5 Phases of type “draw-multiple-areas”

Phases of type `draw-multiple-areas` are meant to show on a single page a list of neighborhoods or areas the participant can draw on the map. This differs from a group of sequential `draw-area` phases because, here, the respondent can choose only some of the many areas to draw, not going through a much bigger number of phases which areas he doesn't know how to draw.

However, as participants select one of the areas to draw, we figured it made sense to lead them into a `draw-area` phase, properly configured for the target area. As such, the best way we found to do this was to provide, in the `draw-multiple-areas` specification, a `subPhases` property. As the name indicates, this attribute is an array where each element represents a `draw-area` phase which the participant will navigate to temporarily, going back to the `draw-multiple-areas` parent phase when finishing the drawing.

In Figure A.10 you can see a possible specification for a `draw-multiple-areas` phase. Just as a `draw-area` phase specification, detailed in Section A.4, this includes the `title`, `description`, `instructions`, and `mapView` properties (`mapView` object detailed in Section A.3). It adds, however, the `subPhases` attribute, as previously mentioned, described as an array of objects, where each represents a sub-phase. The sub-phase object is itself described by three attributes: `name`, `areaNumber`, and `phaseData`.

The first is the area's name, meant to identify it among the list of areas this phase displays.

The second property, `areaNumber`, wasn't originally included in the specification, as we thought that sub-phases would be identified by their index on the `subPhases` array. However, as we implemented both web-apps, we noticed that such property was needed to assure correct functioning. It should be noted that there's no need to guarantee any particular order when configuring those numbers, and the designer just needs to make sure that all `areaNumber` are different from each other.

```

{
  "type" : "draw-multiple-areas",
  "title" : "Draw neighborhoods",
  "description" : [
    "We want to find true boundaries.",
    "This is one way to do it..."
  ],
  "instructions" : [
    "Draw as many areas as you like",
    "When ready press 'Next'"
  ],
  "mapView" : {
    //a mapView object
  },
  "subPhases" : [
    {
      "name" : "Bronx",
      "areaNumber" : 0,
      "phaseData" : {
        //a draw-area specification object
      }
    },
    //another area to draw
  ]
}

```

Figure A.10: Specification of a “draw-multiple-areas” phase.

The `phaseData` property is described as an exact draw-area phase should be described, including every attribute we talked about in Section A.4. This could be exhaustive for the survey designer, and is indeed something that points for the use of a “survey creator” tool to bring usability to the creation of phases such as these. However, such thing was left for future improvements, since it wasn’t a critical feature for our framework.

Finally, still regarding the phase specification, note that even though this phase doesn’t directly include a map interaction, we figured to be best we added a `mapView` object to accommodate a preview over the map before loading any sub-phases, thus smoothing the constant and repetitive transition from parent-phase to sub-phase.

The input a draw-multiple-areas produces follows the same idea as the `subPhases` object, as it is described by a set of draw-area input objects. This particular set is described as an object, containing one property for each sub-phase the participant visited, see Figure A.11.

```

{
  "1" : [
    //polygons drawn on subPhase with areaNumber 1
    [
      //polygon 0
    ],
    [
      //polygon 1
    ]
  ],
  "7" : [
    //polygons drawn on subPhase with areaNumber 7
  ]
}

```

Figure A.11: Specification of the input object produced by a “draw-multiple-areas” phase.

An object representation was chosen over an array for the same reasons that lead us to include the

`areaNumber` property. This choice assures the correct indexing of areas, since the property name on the input object is the same as the sub-phase's `areaNumber`.

As for the value of those properties, as mentioned, they follow the same structure as the input produced by a `draw-area` phase, described on Section A.4 and observable on Figure A.9.

