Masters Program in Geospatial Technologies

Mapping changes in spatial cognition of public spaces at NOVA University Lisbon (Campolide Campus) caused by COVID-19 restrictions, using GIS and perception.

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Mapping changes in spatial cognition of public spaces at NOVA University Lisbon (Campolide Campus) caused by Covid-19 restrictions, using GIS and perception.

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DECLARATION OF ORIGINALITY

I declare that the work described in this document is my own and not from someone else. All the assistance I have received from other people is duly acknowledged and all the sources (published or not published) are referenced.

This work has not been previously evaluated or submitted to NOVA Information Management School or elsewhere.

Lisbon, February 1, 2021.

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ABSTRACT

The global pandemic produced by COVID-19 has caused many changes that not only concern public health, moreover, is producing social effects that show differences in the perception and construction of spatial cognition that modify the way people live public spaces. To study these modifications, the thesis analyzes the changes in the perception and spatial cognition in public spaces at NOVA University Lisbon bringing a different focus and knowledge that can be used to understand how the pandemic crisis is affecting the social relationships in these public spaces.

In order to gather information that allows to demonstrate the main perception of participants, a survey was developed, including three fundamental sections. One focus on before pandemic restrictions where there was no limitation or concerns about the contagion of the virus, a second one after pandemic restrictions where different health restrictions have been applied and have produced effects in the way people interact to each other in the public spaces. A third section tries to collect information about the perception of restrictions implemented in the study area.

The survey was shared online with different students, professors and staff. The collected information was composed by drawn polygons and questions that participants answered related to the public spaces at the study area like the cafeteria, canteen, natural areas, benches, study rooms, library, offices and corridors. Results were analyzed showing the two main sections. The main analysis carried out was the survey data analysis, overlapping analysis, spatial distribution by sociodemographic characteristics, hotspot analysis and cluster analysis. Results show what were the changes and differences in the frequency and use of public spaces before and after pandemic restrictions.

KEYWORDS

Covid-19 pandemic

Geographic Information Systems

Geospatial survey

Health

Perception

Public space

Restrictions

Space

Spatial analysis

Spatial cognition

ACRONYMS

WHO – World Health Organization.

QR CODE- Quick Response Code.

GIS – Geographic Information System(s).

ISQ – Instituto de Soldadura e Qualidade (Institute for Welding and Quality).

XML – Extensible Markup Language.

COVID-19 – Coronavirus Disease.

NOVA IMS – NOVA University Lisbon, Information Management School.

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1. INTRODUCTION

1.1 Problem Statement

The situation caused by the COVID-19 outbreak has produced many changes that do not just bring up health issues, but also economic, political, social and cultural effects that have been transforming the way people interact with each other and live in society. The different measures applied such as social distance, use of face masks, application of sanitizer and restriction of number of people in closed spaces have been implemented in many countries around the world (World Health Organization [WHO], 2020).

The first reported cluster of pneumonia in Wuhan (China), was identified by the Municipal Health Commission, as a novel coronavirus on December 31st, 2019. On March 11th, 2020, the World Health Organization made the announcement that COVID-19 could be characterized as a pandemic because of the alarming levels of spread and severity of the new type of the virus ([WHO], 2020b). During the year 2020, every country has had different virus propagation rates, proportions of cases and deaths, waves of spread, but also different legal and political measures to tackle the issue.

The pandemic outbreak caused by COVID-19 has made people adjust their daily routines, social interactions, work dynamics, as well as travelling depending on the countries and their prevailing (current at the time) pandemic regulations. This change of behavior in daily activities aimed to control the pandemic, impacting the use of public spaces. As Honey-Roses et al. (2020) mention, "*restrictions on the use of public space and social distancing have been key policy measures to reduce the transmission of SAR-CoV-2 and protect public health"*. In this regard, the knowledge about the public spaces and their use have a critical impact in the pandemic that contributes to the design of public policies that help controlling the contagion and spread of the virus.

This change in the use of public spaces is also evident at universities and schools that have to apply new measures including restrictions on movement and frequency of presential classes. At the Information Management School from the NOVA University Lisbon in Portugal ([NOVA IMS], 2020a), different restrictions have been set up

following the contingency plan and resolutions of the Council of Ministers. This has influenced in reducing the attendance of public spaces, the closure of study rooms, a strict control in accessing classrooms, digital check-in system to manage the attendance of specific areas using QR code, mandatory use of face masks indoors, constant application of hand sanitizing gel and new communication channels with the rectorate in case of any symptom or issue related to the pandemic.

In addition, NOVA IMS was granted the "COVID Out" recognition, which is a seal provided by the Institute for Welding and Quality (ISQ) claiming that "*all the needed measures are already to assure that everyone will be able to work well in the facilities with the maximum levels of safety, protecting the health of students, faculty, staff and visitors"* (NOVA IMS, 2020b). Furthermore, the institute counts with a Contingency Plan and Regulation, which helps the organization with managing, supervising and checking the progress of the activities carried out during the pandemic in the Campus. The restriction of presential activities have produced noticeable effects on the use of public spaces at university, shaping new patterns of social interaction represented in its spatial distribution.

1.2 Motivation

The study of this thesis can provide a different way to analyze and describe the new spatial behavioral patterns caused by the restrictions in order to control the spread and contagion of COVID-19. The development of new technologies to gather and store spatial data has increased the analysis of information that is processed to provide patterns of distribution that could be used to elaborate action plans and strategies made by governments and decision makers. In this sense, Geographical Information Systems (GIS) have been supporting the integration of geospatial information to integrate the data located and referenced, providing multiple analysis and results used in different fields such as urban planning, surveying, health services, environment, data science and computer science. Also, GIS has been used in different applications to study epidemics and health diseases that have a spatial distribution. GIS software is created to enhance the tracking, routing, documentation, monitoring, analysis, management and mapping of the resources of health and environment (Ulugtekin et al., 2016).

The importance of this study also resides in linking the elements of spatial cognition, the perception of public spaces, GIS and the COVID-19 epidemic outbreak to provide an alternative interdisciplinary framework that can be added to the current research scenario. As new restrictions and limitations of social interactions take place due to the pandemic, the study of their effects is crucial to provide new strategies or to improve the existing ones in order to reinforce the measures that can aid to the sanitary situation. Considering that the spatial analysis of the pandemic outbreak also has assisted universities, organizations and governments all around the world, this research can extend the knowledge of the COVID-19 though a case study on the analysis of change in the perception of use of public spaces at NOVA University (Campolide Campus).

As Pardo et al. (2020) mention, "*the generation of information is one of the keys to confronting Covid-19"*. Also, the role of GIS has been determinant to study the pandemic outbreak, becoming a relevant tool for analyzing and visualizing the spread of the contagion (Mollalo et al., 2020). A noteworthy example is the GIS dashboard developed by John Hopkins University Center for Systems Science and Engineering, in which they provide live data of the COVID-19, which is present everywhere in the media, providing information on the total numbers of confirmed cases, mortality and recovered patients ([JHU CSSE], 2020).

Finally, this thesis can also provide knowledge using perception that can be applied to design new measures of control. The measures implemented during the quarantine in conjunction with self-isolation and multiple related issues such as limitation of social activities, increase of virtual activities, and risk of contagion have significantly impacted the way of perceiving and thinking about space. Therefore, people's perception and spatial cognition in public spaces has been influenced by new perspectives on safety related to the risk of infection.

1.3 Research Questions

After bringing forward the motivation of this thesis, research questions are outlined:

- How has the frequency in the use of public spaces at NOVA University Lisbon (Campolide Campus) changed due to the COVID-19 restrictions?

- What are the main differences in frequency according sociodemographic characteristics?
- What is the main perception of participants about the use of public spaces at the study area during COVID-19 outbreak?
- What are the main changes of spatial cognition inferred due to COVID-19 at the study area?

1.4 Objectives

The aim of this thesis is to study the changes in people´s spatial cognition of public spaces at NOVA University Lisbon (Campolide Campus) caused by COVID-19 pandemic restrictions using GIS and spatial perception. The specific objectives are:

- To present the frequency in the use of public spaces at the study area during the COVID-19 outbreak.
- To analyze the perception of participants about publics spaces before and after COVID-19 restrictions in the study area.
- To infer the differences in spatial cognition before and after the COVID-19 restrictions of public spaces at NOVA University Lisbon (Campolide Campus) based on a perception questionnaire.

1.5 Thesis structure

The thesis is divided into six chapters. The introduction chapter frames the general research background with the problem statement, motivation, research questions and objectives.

The second chapter of Literature review describes the basic theoretical elements, concepts, and authors about the study. It starts with the explanation of space and public space to continue with the theory about perception, cognition and spatial cognition. Then the relation between spatial cognition and Geographical Information Systems is done to finalize with the restrictions and effects on public spaces due to COVID-19.

The third chapter is about the Methodology, which describes the general elements, the process of the data collection, data preprocessing and the explanation about the analysis.

The fourth chapter describes the Results of the analysis, which includes overlay analysis, spatial distribution, spatial perception of public spaces and statistics

The fifth chapter explains the Final Discussion regarding the evolution of perception of public spaces due to covid-19. And the sixth chapter presents the conclusions of the study.

2. LITERATURE REVIEW

2.1 Space and Public Space

Defining space is an extensive process because the concept is the object of study of many sciences and disciplines such as mathematics, physics, architecture, urbanism and geography. Space in a general conception allows to delimit and frame the data that can be integrated, related and structured into a whole (NRC, 2006, as cited in Wakabayashi and Ishikawa, 2001), by abstracting its fundamentals with geometric elements such as distance, coordinates, and dimensions (Wakabayashi and Ishikawa, 2001). For this thesis, the concept of space will be constraint by the geosciences field, described as "*the extent of an area, usually expressed in terms of the Earth's surface"* (Mayhew, 2009). Space leads into the concept of spatial, which presents many applications in different definitions such as spatial analysis, spatial autocorrelation, spatial differentiation, spatial diffusion, and spatial cognition which particularly will be reached in the next pages.

Space delimited in geosciences can as well be studied by different approaches like in environmental psychology, spatial cognition, and behavioral geography, described as properties of objects in an environment (Hart & Conn, 1991 in Golledge & Stimson, 1997), or by the "*Kantian sense of being a container in which human action takes place after the processing and manipulation of information sensed in the spatial container"* (Golledge & Stimson, 1997), associated with "*the Newtonian, container-like conception of the physical world, located and referenced in the three dimensions"* (Hubbard & Kitchin, 2011, in Koops & Galic, 2017). Space can express a delimited area that includes all the processes, characteristics and elements that are products of human action in relation to the environment where the multiple interactions of human behavior are located to be reproduced.

The concept of space is studied in different ways that depends on many characteristics like the context, study area and focus. For example, Lefebvre (1991, in Koops & Galic, 2017) explains space as part of the social production instead of just an isolated object. Hubbard & Kitchin (in Koops & Galic, 2017) using a humanist insight, describe space as a meaningful world of people's life adding that space is not a framework of geometric relationships. As Couclelis and Gale mention (1986, in Mark & Frank,

1991), space has different manifestations and expressions like the Euclidean, physical, sensorimotor, perceptual, cognitive, and symbolic one.

In addition, space is associated to "*a three-dimensional expansion of any kind, as a scene for social life, formed by physical factors with their different dimensions, proportions and special features"* (Hillier, 2008, in Biveva, 2012). In this sense, real space is added as a group of interconnected spaces that people inhabit to develop their activities and routines, leading to relationships between the physical characteristics and the social relationships (Biveva, 2012). Space includes all physical dimensions that links with the human actions placed there.

The concept of public space derivates from the study of space in the context, considering many approaches that are based in the urban structures, society and culture. To frame this concept, Hanzl (2013) mentions that the main issues to be held are the physical features, identified as the characteristics of the objects such as distribution, shape and size; distribution of the activities of users that reflects the social component; and the flow of human movement, which has their delimitation in the layout of a given place.

Public space is the main urban space where the urban actions are developed in different ways of socialization and integration with the elements of transport, infrastructure and facilities. Public space allows the human interaction and the development of freedom where people can play, practice an activity, recreate, coexist and express themselves. Public space as free urban space allow "*the daily exchange of experiences between the inhabitants and modelling the perception of them regarding the city"* (Fernandez & Arpa, 2008, in Jankovič, 2015)

Public space is also referred as an accessible area to all people with no distinction of any racial, demographic, ethnical, political, religious or socio-economical characteristic that includes different places like plazas, squares and parks connected by the urban morphology (Educational, Scientific and Cultural Organization [UNESCO], 2020). These public spaces allow to reinforce the identity of the inhabitants, changing their perceptions and building the sense of belonging with the recognition of specific areas where people can feel security and comfort. They also

promote the intercultural exchange being a meeting point of many social expressions such as the language, beliefs and traditions.

2.2 Perception, Cognition and Spatial Cognition

To frame the description of spatial cognition and spatial perception it is necessary to start with the basic elements of the concepts that sometimes are misinterpreted. Perception has been studied by geographers in the sense of how things are remembered or recalled by people (Golledge and Stimson, 1997), but nevertheless other specialists like psychologists have associated the perception as a subset or function of cognition, therefore the confusion and difficulty to explain and distinguish both terms.

Werner and Kaplan (1963, in Golledge and Stimson, 1997) see perception as an inferential process in which a person plays a maximal and idiosyncratic role in interpreting, categorizing, and transforming stimulus input. An individual receives the signals through his or her senses by sight, hearing, smell, taste, and touch. Perception implies psychological processes that respond to the external stimulus got by the different senses. Every person has a distinct perception because the stimulus and the way the body reacts to them are changed by sociocultural, physiological and psychological characteristics.

The information received is experienced, recorded and selected from the rest in order to keep just what is necessary for the person (Golledge and Stimson, 1997). The mental process separates data that is relevant for each one according to their interests and motivations. Every person has different experiences and perceptions of reality that also depends on the capacity to get the information and the way of process, even if the spatial and temporal characteristics of the external world are the same. Perception contains different properties of objects and things that differ in shape, color, texture, direction, quantity, taste, height, structure or another that can be relevant for the stimulus produced in the senses and processed in the mind.

Cognition is a different concept that refers to the way information, upon perception, is coded, stored, and organized in the brain so that it fits in with a person's accumulated knowledge and values (Golledge and Stimson, 1997). By these means, to indicate the

difference between perception and cognition one could say that perception is part of a higher mental process that include other complex elements and functions constantly changing to restructure the information as shown in the following figure:

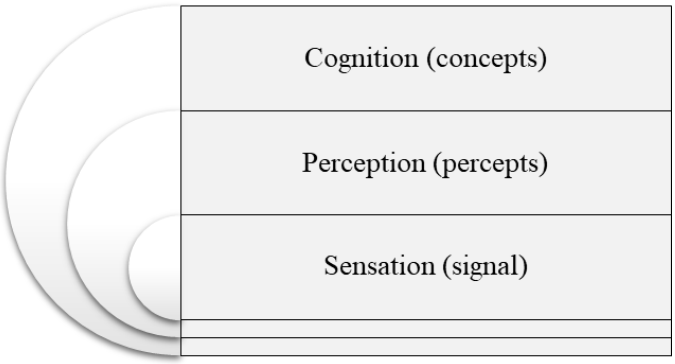

Figure 2.1. Sensation-Perception-Cognition model of human interaction with their environment (from Panchanathan et al., 2008).

Cognition described by Tversky, is situated by facts about our bodies and the world they inhabit (2008). Every human life has physiological and cognitive process to interact with the environment, developing skills and abilities in order to survive. Bodies and the world have properties that afford, enable, and constrain perception and actions in the way of living. Cognition allows to codify and use information based in signals that are perceived in conjunction with the experiences acquired.

Spatial cognition within cognition area, studies the knowledge of spatial characteristics and actions that happen in the world as of its acquisition, storage, retrieval, manipulation and use by humans, animals and intelligent machines. This includes complex and multiple process like sensation, perception, thinking, imagery, learning, language, reasoning and problem solving about the physical and social space that includes properties of location, size, distance, direction, separation and connection, shape, pattern, distribution and movement (Smelser & Baltes, 2001).

Different questions concerning the way human beings acquire spatial information, and the representation, communication and use of geographic information are constrained in the study of spatial cognition. In this regard, space again becomes a fundamental part of spatial cognition and spatial thinking. All the activities that people develop are located. For the survival and adaptation in the world, humans had to be conscient about the environment through many cognitive processes in order to get food, water, shelter

and other facilities (Tversky, 2008). Nowadays, spatial cognition helps to identify and understand the relationships that people have with places and areas in the geographical space. Spatial cognition includes different mental operations that involve perception and behavior, depending on the physiological characteristics of individuals and the form they represent and analyze the information. As thoughts, the ideas about space differs from person to person, being part of a complex representation of the external and internal world.

2.3 Representation of perception and spatial cognition in Geographic Information Systems.

The representation of spatial perception and cognition has traditionally been studied by different methods and tools. One of them is the cognitive map defined as the "*long-term stored information about relative location of objects and phenomena in the everyday physical environment"* (Golledge & Stimson, 1997), which provides information to the analysis of the spatial representation of individuals. Cognitive maps show complex relationships between the space, time and attributes experienced by every person.

In that context, Geographical Information Systems (GIS) have contributed to include cognitive elements with different analysis that can be stored, georeferenced and visualized. GIS do not just identify phenomena, objects and elements, they also process and relate everything with a location on Earth´s surface, symbolizing and coding the perceptions and spatial thinking of people. Moreover, the development of technology and the increase of geographical data has impacted in the study of spatial cognition with different applications like decision making and change of perception to visualize the external world. Different applications and technologies are having an impact on the questions and methods of spatial cognition like GPS (Wakabayashi, 2003) while other are focused in the use of augmented and virtual reality, evolving the paradigm of representation about the space.

There is no doubt that every human mind and body has a different capacity to analyze the spatial information, nevertheless GIS has contributed to code and visualize geographical information through many manipulative processes (figure 2.2.). Different

tasks that include the visualization, processing, analysis and storing of spatial information have been performed by GIS, bringing advantages like the reduction of time and cost and the constant study of the relationships between people and its different assumptions of space.

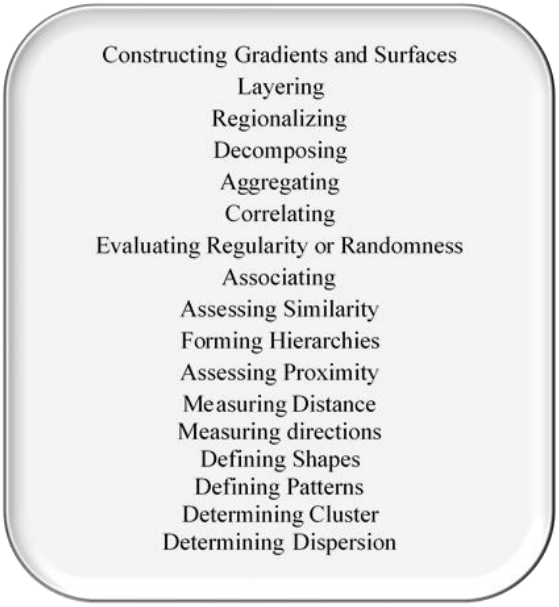

Figure 2.2. Samples of manipulative processes used in cognitive mapping and GIS (from Golledge & Stimson, 1997).

To do the spatial cognition representation in GIS, three different spatial abilities are identified and integrated: spatial orientation, spatial visualization and spatial relation. The spatial orientation facilitates the comprehension of visual components in a different perspective, the spatial visualization allows to manipulate the spatial objects, and the spatial relation includes the analysis of patterns with different characteristics such as color, texture, shape, etc. (Albert & Golledge, 1999). These abilities are a fundamental part of the complex knowledge that involves spatial and geographic science. These abilities constitute GIS elements that study the properties of objects taken from the internal world associated with perception, and the external one related with the geographic characteristics, providing feedback for the spatial cognition of reality.

2.4 Impact of COVID-19 in public spaces.

COVID-19 outbreak has produced many changes in the social interaction of all the world that has not evidenced just the health consequences, but also the influence in the human relationships with results on the way the space is used, frequented, lived and perceived. The frequency and use of public spaces show changes that are the product of restrictions to prevent the contagion of the virus. The COVID-19 pandemic has modified people's relationships with the streets, public spaces, natural areas, and public facilities such as schools, universities, libraries, and hospitals in a new way of interaction. The different restrictions in all the world such as physical distancing are producing a reduction of personal interactions that increases social isolation and exclusion inside the spaces of the cities (United Nations Habitat [UN Habitat], 2020).

Public spaces in this sense, have had an important role in the design of health policies applied in urban areas. In some cases, the use of public spaces has been limited or reduced, while in other they have been spaces to promote mental health during the sanitary situation. Nevertheless, the situation that varies from region to region is reshaping the way how people conceive, perceive, and use public spaces. Nowadays, many professionals are studying the way the crisis is transforming the relationships of people with public spaces (Alter, 2020, Florida, 2020, Roberts, 2020, in Honey et al., 2020).

Different examinations and topics have been identified to study the effects that COVID-19 has had in public spaces like the use, behavior, perceptions, design and social consequences including exclusion and inequities (Honey et al., 2020). Regarding the change of perceptions and design of public spaces, figure 2.3 shows the main questions considered on these areas. Other authors like Jasinski (2020) consider the social segregation as a product of changes in the use of public spaces due to restrictions like distance of tables in restaurants and benches, or even the digitalization of social life.

Use, Behaviour and Perceptions	Design
1. Will we observe fewer people in public? 2. Will we change what we do in public? 3. What is the future of large public gatherings? 4. Will our perceptions of public space change? 5. Will our intuitive carrying capacity for public spaces decrease? 6. What will be the impacts on public transit? 7. What will happen to micro-mobility and mobility sharing? 8. Will we observe changes in the use and regulation of interior public spaces? 9. Will we experience infringements on civil liberties?	1. Will the temporary transformations during the crisis inspire permanent changes? 2. Will streets be re-designed? 3. Will the pandemic accelerate the mainstreaming of health criteria into the design of public spaces? 4. Will green space planning need new designs, uses and practices? 5. Do we need a new typology for public space?

Figure 2.3. Summary of the emerging questions about how the COVID-19 episode may change the design, use, behaviors, and perceptions in public space (from Honey et al., 2020).

The change in the frequency of use of public spaces is produced by different perceptions that are related to the thinking of freedom where people can escape from the digital invasion caused by the pandemic, or other effects like isolation from social interaction, stress and sedentarism. Other people's perceptions are related to the high risk of contagion that evidence social inequalities and reinforce the safeness of home (Devine, et al., 2020). The constant advices and regulations implemented to the population modifies people's perception impacting in the use and frequency of public spaces around the world based on negative and positive experiences.

2.5 GIS &COVID-19 Bibliometrics

The COVID-19 health crisis has brought an increase in the participation and production of scientific papers to study the current situation aiming to provide knowledge and a better comprehension of the phenomena. Because of it, this section tries to frame information that can support the thesis using bibliometrics about the productivity of papers related to the topic during 2020. Bibliometric studies have been used as an instrument that allows the evaluation of scientific productivity for the support of Master thesis (Solano et al. 2009). The presentation of these bibliometrics support the literature content because it helps to frame the current and latest research oriented to study of the topic.

The information considered in this analysis has been taken from PubMed database (National Center for Biotechnology Information, n.d.). First, a selection of papers that included keywords like "COVID-19" and GIS was done, which gave as a result 67 articles. Secondly, with the selected information some analysis was performed in "Bibliometric R" (n.d.), which is a group of open-source tools that make quantitative analysis of scientific papers from journals like "Scopus", "PubMed" and "Digital Science Dimensions".

As a result, figure 2.4 shows the countries that are producing papers about COVID-19 and GIS, indicating major participation those with dark blue colors like the case of USA and India. Red arrows represent the link between the countries that have international cooperation for the analysis of the topic selected. This map shows a view of the productivity of papers that gives a general view of the state of art. Figure 2.5 shows the co-occurrence network of the articles showed in PubMed. The network gives a broad representation of the group of words found in the articles searched. The most frequent words found were "COVID-19", "pandemic", "humans", "Geographic information systems", "spatial-temporal analysis", and "model". This bibliometric visualization provides a broad comprehension about the current research related to this thesis.

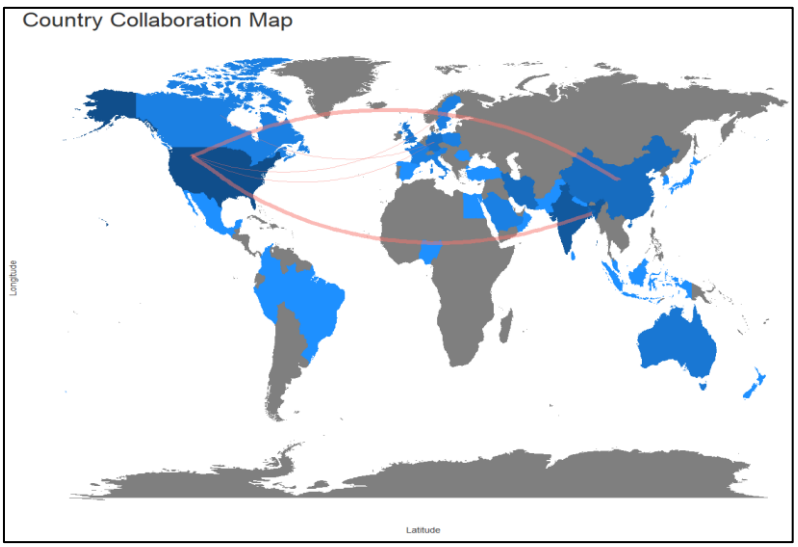

Figure 2.4. Country Collaboration Map of Pub Med data base search with COVID-19 and GIS keywords.

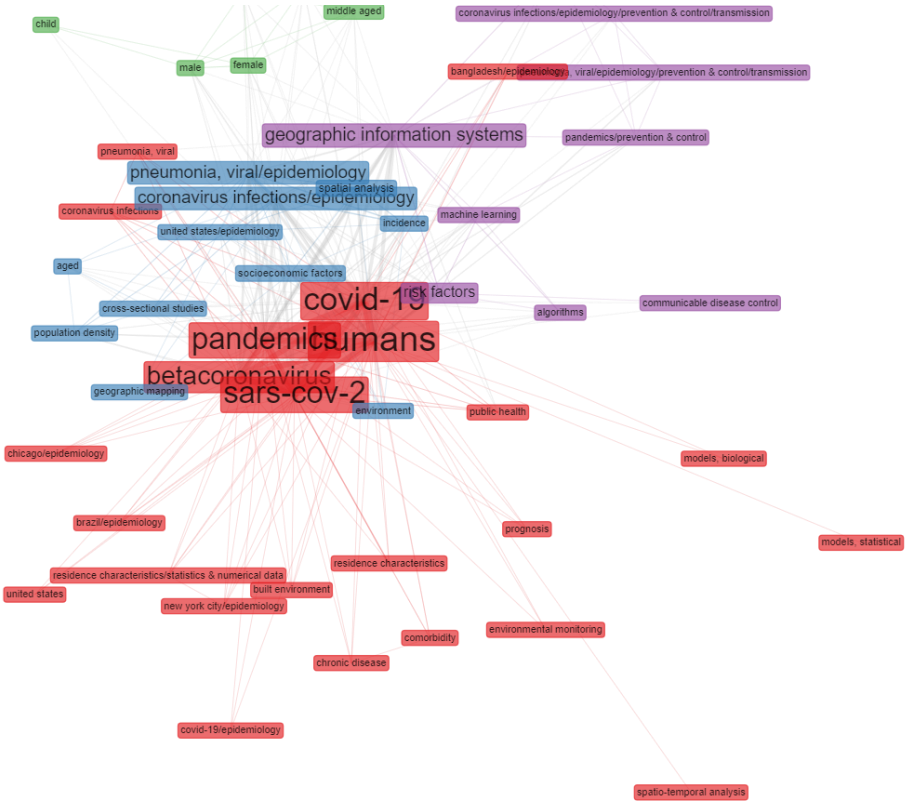

Figure 2.5. Co-occurrence network of Pub Med data base search with COVID-19 and GIS keywords.

Figure 2.6 presents the most relevant sources in the search of papers that can guide further analysis related with the topic of study. In addition, this metrics show the current production with the number of documents and analysis that can be considered in the field of GIScience and the pandemic of COVID-19. The most relevant Sources were the "International Journal of environmental research", "the science of the total environment", "environment development and sustainability" and "modeling Earth systems and environment". Finally, figure 2.7 shows the graphic of the most relevant words found in the database from PubMed, which were "humans", "COVID-19", "Sars-Co-2", "pandemic" and "betacoronavirus".

The analysis of bibliometrics gives a useful tool that helps for a better comprehension of the pandemic through the production and collaboration of papers from the different journals, institutes, and centers of research. Currently, many of the research focused on the study of the pandemic from different study areas has brought a global cooperation that tries to give a better comprehension of the sanitary crisis. Also, the different policies of open access have contributed to increase the channels of information with data that can be analyzed for academic purposes.

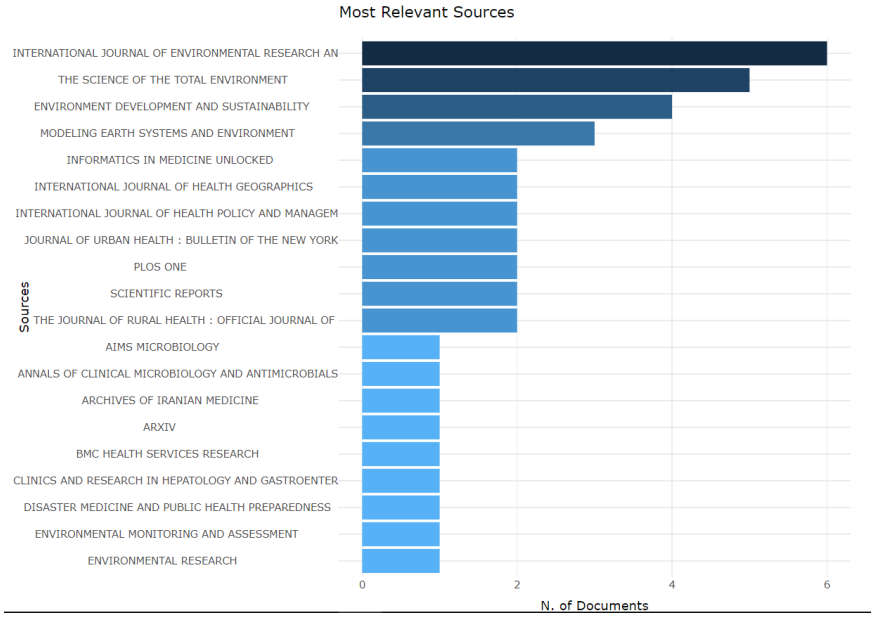

Figure 2.6. Most Relevant Sources of Pub Med data base search with COVID-19 and GIS keywords.

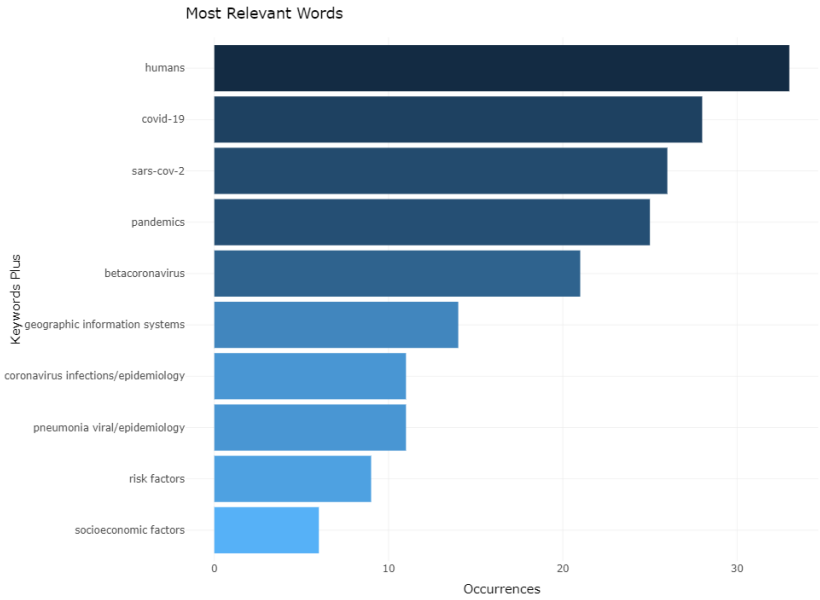

Figure 2.7. Most Relevant Words found in the selected paper from Pub Med database.

3. METHODOLOGY

3.1 General Framework

In order to investigate the changes of spatial cognition and people's perception of public spaces at NOVA University Lisbon (Campolide Campus), a survey was designed and implemented. The information from the survey was analyzed to show the changes produced by the COVID-19 pandemic of public spaces at NOVA University Lisbon (Campus of Campolide). The methodological steps are shown as follows (figure 3.1).

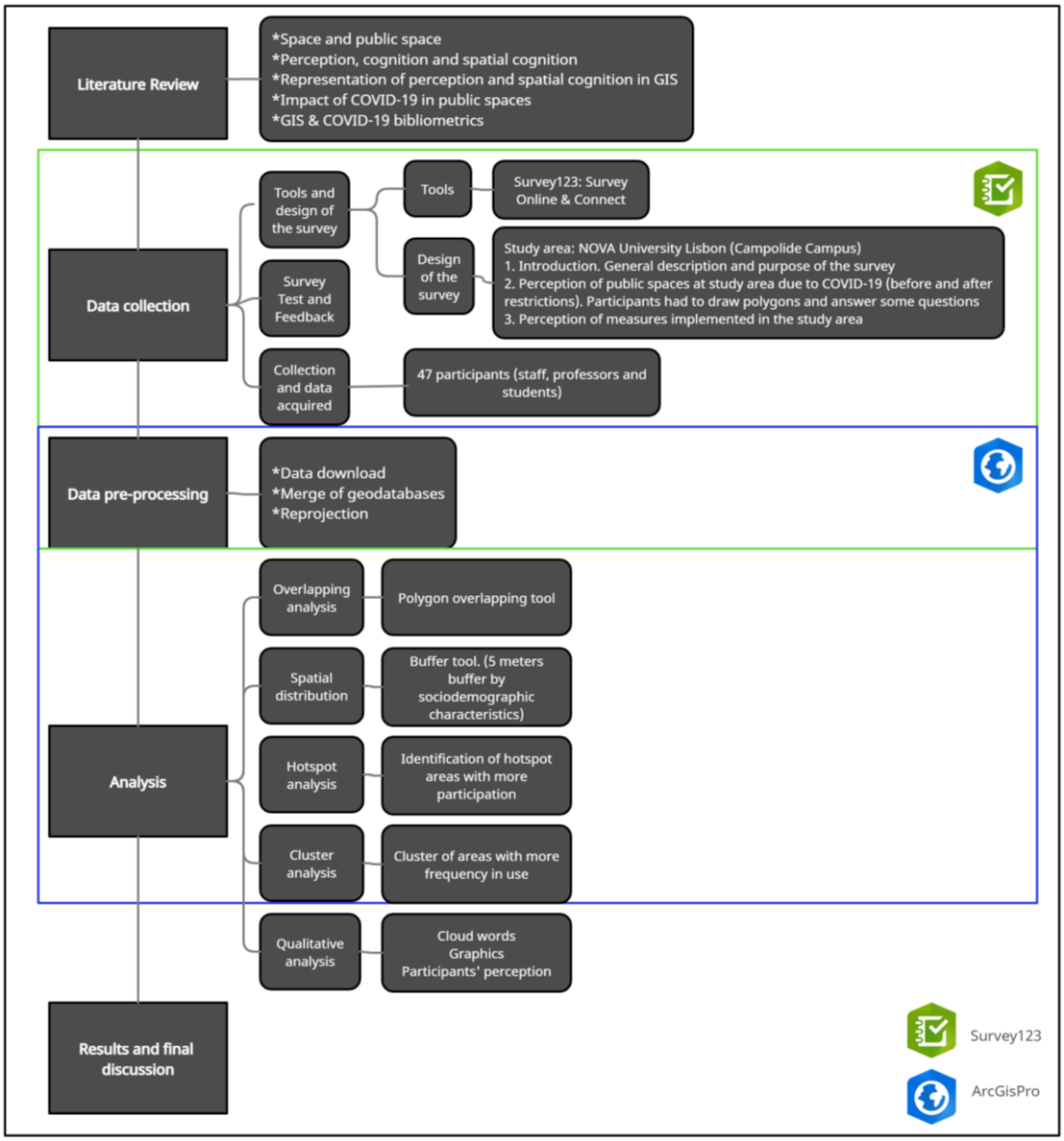

Figure 3.1. Flow chart of the methodology.

3.2 Data Collection

3.2.1 Design of the Survey, tools and feedback

The first step to collect the data was to design a survey, so It was decided to use Survey123 software because it provides a group of tools that allow the interoperability between data acquired and GIS. Survey123 is an ArcGIS tool developed by ESRI that allows creating, sharing, downloading, analyzing and visualizing data got from the surveys as well as the production of general statistics. Survey123 creates smart forms with different functions for multiple languages (Environmental Systems Research Institute [ESRI], n.d.a). The information is stored in an ESRI account for further analysis, where data is available and matched to process in ArcGIS platform.

To work on Survey123 it was necessary to use and combine two platforms integrated in the application, Survey123 online (web designer) and Survey123 Connect (desktop application) because of the characteristics of each one like technical constraints and design. On Survey123 online the general design, structure and sharing of the survey was performed, providing the manage, control to access and visualization of the data that the app offers (ESRI, n.d.b). On Survey123 Connect more complex processess were carried out such as the delimitation and integration of the study area, incorporation of *geoshape* queries (questions that asks to the users to draw specific polygons of an area related to a topic) and changes for the final edition of the survey.

Both platforms in Survey123 are constantly updated so it helps to make changes in each of them. The basic format file is an *XLSForm* spreadsheet, which is a standard format created to assist in the simplification of the authoring or forms in Excel (XLSForm, n.d). The basic format (excel workbooks) consists of two main worksheets that are survey and choices, with an extra optional worksheet of settings that helps to specify the properties of the form. The *XLSForm* edited in Survey123 Connect allows to manage the format of questions, set parameters, add extra information and edit the visualization of the survey.

The Excel worksheet of the survey presents in the column's information related to the type of questions, the name of them, labels, hints, constraints and other specifications depending on the design. In the row the different elements of the survey can be added by specifying their elements and structure as shown as the following figure.

type	name	label	hint	constraint
begin group	gro_1			
note	generated_note_surveyDescription_0		This survey is part of my thes	
note	generated_note_surveyDescription_1			
note	generated_note_surveyDescription_2			
end group				
select_multiple list_no	notice_of_privacy	Notice of privacy	The information provide	
begin group	gro_2			
note	generated_note_section_1_general_information	SECTION 1. GENERAL INFORMATION		
select_one list_where_	where_are_you_from_birthplace_c	Where are you from (Birthplace countr		
select_one list_how_o	how_old_are_you	How old are you?		
select_one list_what_i	what_is_your_gender	What is your gender?		
end group				
begin group	gro_3			
decimal	what_is_your_current_zip_code_i	What is your current ZIP code in Portug	*Please write the zip cod	
select_one list_what_i	what_is_your_educational_level	What is your educational level?		
text	what_is_your_profession_or_job	What is your profession or job?		
select_one list_how_lc	how_long_have_you_been_in_the_l	How long have you been in the Lisbon r		
end group				
select_multiple list_ho	how_do_you_get_to_nova_ims_camp	How do you get to NOVA IMS Campolic	*You can select more tha	
text	how_do_you_get_to_nova_ims_camp_other	Other		
note	generated_note_section_2_use_of_public_spaces_	SECTION 2. Use of public spaces at NO		
note	generated_note_section_21_use_of_public_spaces	Section 2.1. Use of public spaces BEFO	 <p style="text-a	
begin group	gro_4			
note	ins_1			
begin repeat	geo_1			

Figure 3.2. XLSForm of the survey.

For the purpose of being clear for the users, the survey included different sections with specific questions. The initial part of the survey included a general description explaining the purpose, time expected to complete the activity, specifications and contact in case of any questions or suggestions. Then, the first section of the survey consists of general information related to sociodemographic questions like birthplace country, age, gender, ZIP code, scholar degree and profession or job.

The second section asked about the perception of public spaces at NOVA University Lisbon (Campolide Campus) due to COVID-19, with a subsection 2.1 where participants should have thought about the public spaces such as the cafeteria, canteen, natural areas, benches, study rooms, library, classrooms, offices and corridors that they usually frequented before the restrictions and that spent more time for different activities (working, studying, spending time with friends, etc.). The study area was the Campolide Campus from NOVA University Lisbon, which is in Lisbon city (figure. 3.2) and included spaces like Alfredo de Sousa Residence, Erasmus Mundus Room, NOVA IMS, Library, School of Law and Rectory of Nova University. Alfredo de Sousa Residence is one of the University accommodations that receives many foreign and local students. Erasmus Mundus Room is a place where Erasmus Mundus Students can develop many activities like study, meeting, having classes, etc. NOVA IMS is a high-quality University School in information science and information systems. The NOVA IMS Library is a space where students can consult books, study, do homework and research and read during their free time.

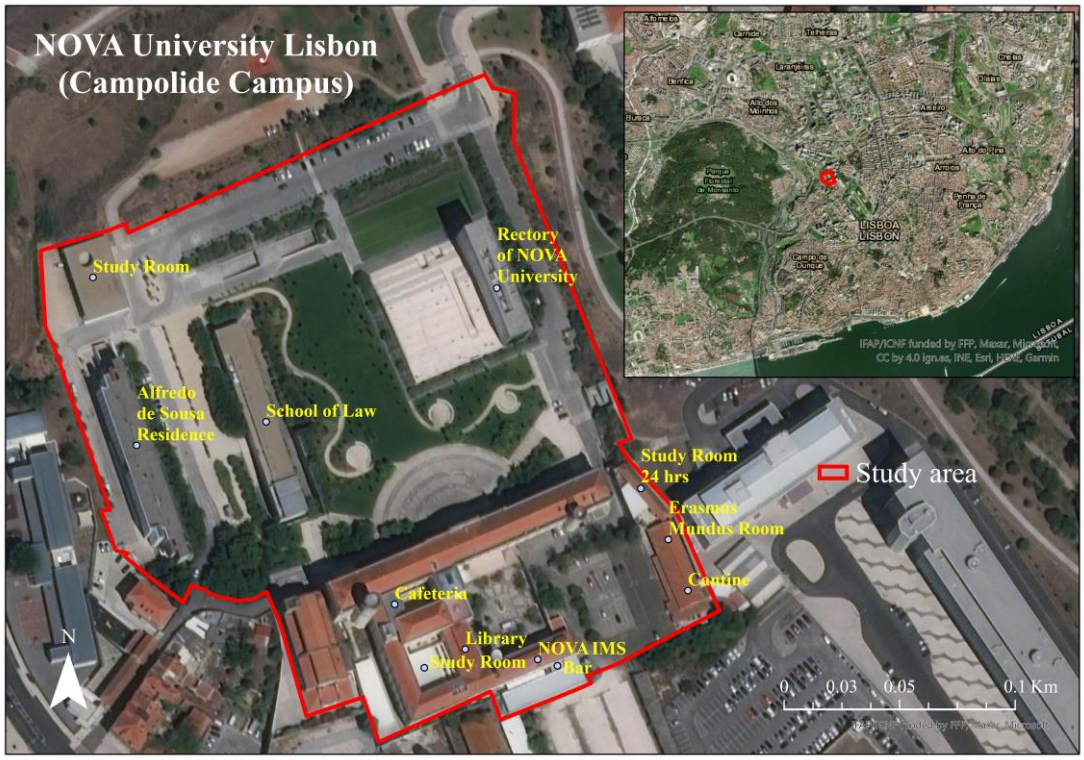

Figure 3.3. Study area. NOVA University Lisbon (Campolide Campus)

Participants had to draw polygons and answer questions linked to the polygons drawn. To do that instructions were included (figure 3.3) as well as a map of the study area (figure 3.4). To achieve the goals of the thesis, this and the following maps were categorized as required questions. Because of the functionality and properties of *geoshape* questions on Survey123, it was just possible to draw one polygon per map, so to add more the users had to aggregate a new map. Finally, some questions related with the drawn polygons and regarding to the time, activities, frequency in use and perception of the public spaces and words that could describe the relationship with the campus at that time were queried.

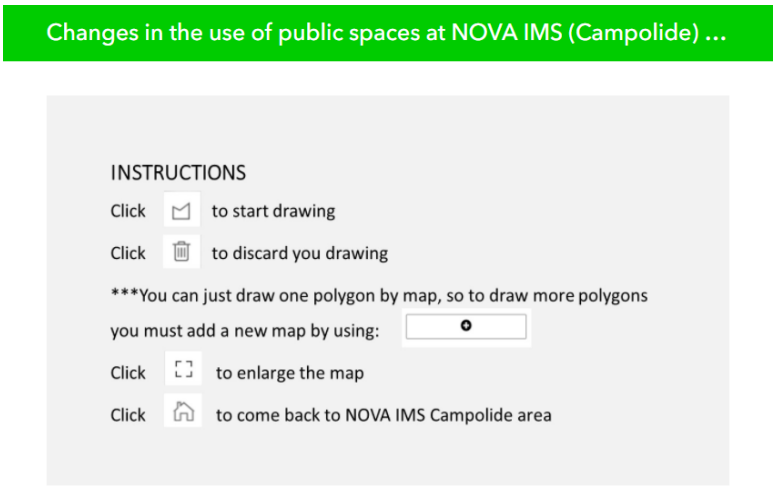

Figure 3.4. Instructions for the *geoshape* questions in subsection 2.1. Public spaces before the COVID-19.

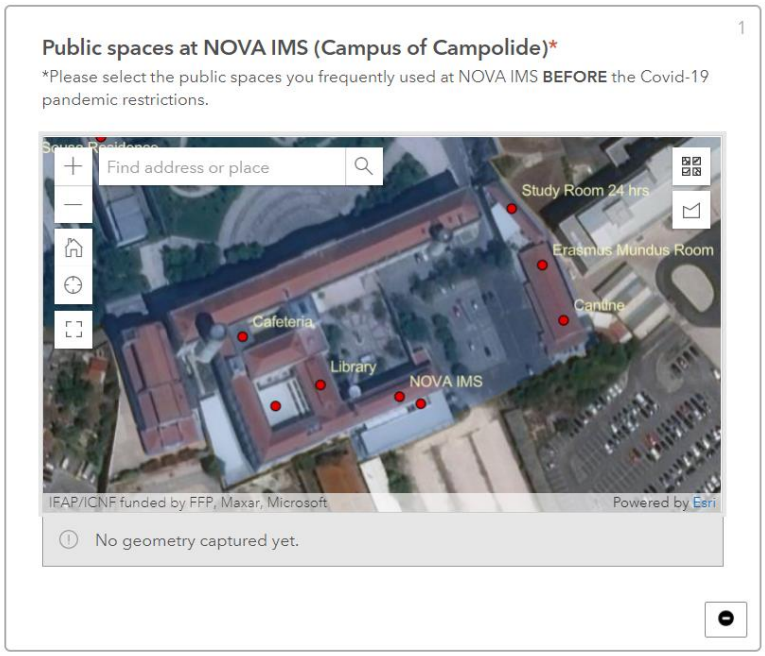

Figure 3.5. Map of public spaces at NOVA University Lisbon (Campolide Campus) with the delimitation of the study area and identification of the main public spaces.

The subsection 2.2., as the previous one requested to the participants to think about the same public spaces at NOVA University Lisbon (Campolide Campus) but after the restrictions implemented. In addition, they had to draw the polygons in a *geoshape* question and continue with the questions regarding the changes in use of the public spaces at the University.

Section 3, which includes questions about their opinion on the measures at NOVA University Lisbon (Campolide Campus) implemented after COVID-19 restrictions tried to look for the participants 'opinion about the restrictions of the following public spaces: cafeteria, canteen, natural areas, benches, study rooms, library, classrooms, offices and corridors. In addition, some questions of preferences about presential and online activities, and frequency of use during all the pandemic situation were requested in the third section. Finally, the fourth section tried to get feedback from the participants about the survey with some recommendations that were useful to improve the data collected for the thesis.

The first version of the survey was applied by a group of seven people that were all familiar with GIS or with drawing polygons on maps. These participants provided feedback about different aspects like the content, the sequence of questions, the redaction, the extent, and the visualization. The main observations were that the survey had relational questions and had a good user interface. Another one was that all the survey was shown in one page, which produced monotony to answer it. Finally, some suggestions were oriented to the design and presentation of the questions for a better visualization.

The main changes followed the suggestions and observations, including the change in format and style into a new one presented in different pages where the participants could see the progress of the completion and distinguish every section of the survey (figure 3.6). Repetitive questions were eliminated and other were reframed. Maps had edition in the labels and delimitation of the study area. The complete survey is presented in the annex (figure 1 to 24).

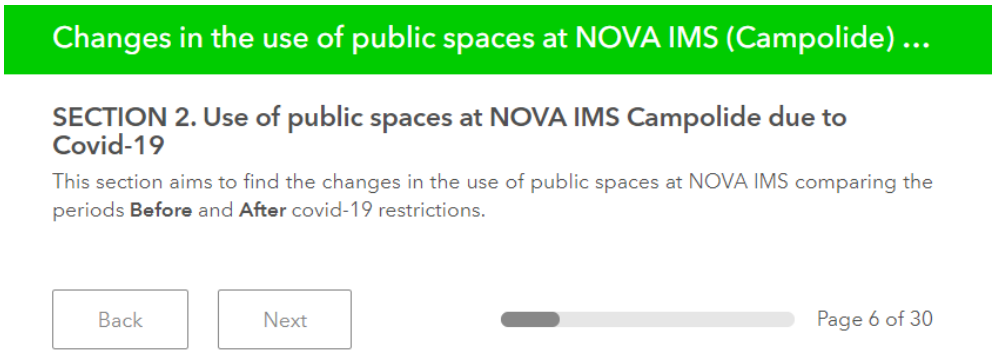

Figure 3.6. Section 2 presented in a page format that shows the progress of the format of the survey.

3.2.2 Survey implementation and data collection

The final version of the survey was shared with students, professors and staff from NOVA IMS (NOVA University of Lisbon Information Management School). People were able to participate if they were developing any activity at university before and after pandemic restrictions. The survey was shared with a link or QR provided by ArcGIS Survey123 Online presentially or electronically via social networks with open access to anyone. The process of collection of the data took approximately 3 weeks. The data acquired was stored and visualized online in ArcGIS Survey123, that presents an interactive platform of the polygons (figure 3.6) and statistics (figure 3.7). The survey was completed by 47 participants that included different age, gender and educational level.

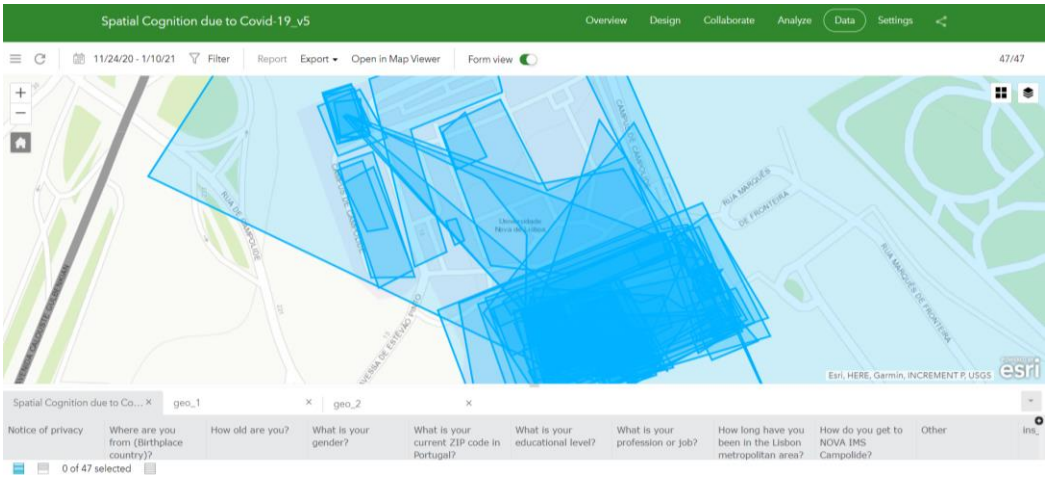

Figure 3.7. Visualization of the polygons drawn by the participants on the survey123 online platform.

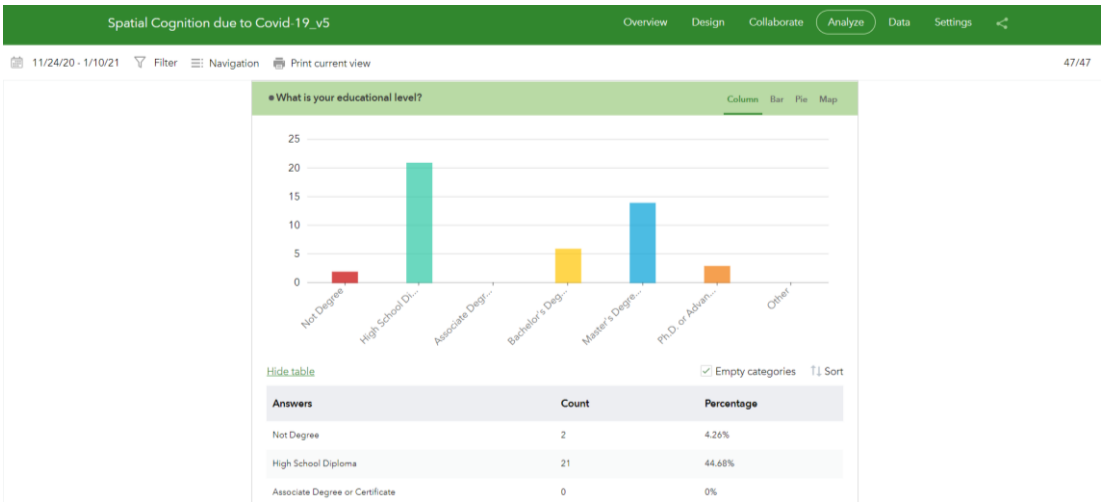

Figure 3.8. Statistics generated from the data collected on the survey123 online platform.

3.3 Data pre-processing

Once the survey was completed, it was necessary to do some pre-processing analysis of the data which was performed in ArcGIS Pro. The data was downloaded from Survey123 in a geodatabase format that included all the polygons for each geoshape question (two in total, one for the use of public spaces in the study area before restrictions, and one after restrictions) where participants were able to hand-draw the areas as the information contained in the survey. Every layer of information contained a common ID related to each participant, so it was possible to associate between them. First, both layers of polygons were joined to create a new one. Secondly, the resultant layer was joined to the table that contained all the answers of the survey. Finally, the layer was reprojected to a metric coordinate system (UTM Zone 29N corresponding to Lisbon) according to the study area.

3.4 Analysis

3.4.1. Survey data

In this section the main results about the participation and polygons drawn of visiting public spaces are presented to introduce general characteristics that could guide the comprehension of more complex analysis. Basic description of population's sociodemographic characteristics tries to show the main factors that could design the changes in spatial cognition. The sociodemographic characteristics indicated the main properties from population that varies from age, profession, educational level and gender. In order to achieve one of the objectives or to answer the research questions of the thesis, the changes in the frequency and use of public spaces in the Campus were analyzed with quantitative description using graphics that could visually indicate the main differences before and after COVID-19 pandemic.

3.4.2. Overlapping analysis

To achieve the objective of presenting the frequency in the use of public spaces at the study area, overlapping analysis was done. The analysis counts the input features that are overlapped, showing a number that can be used to visualize the concentration of areas with more or less frequency of use in the Campus. All the overlapping analysis was carried on in ArcGIS Pro. After counting the number of polygons drawn by

participants, a hexagon tessellation was used for a better representation. Hexagon tessellation are geometric patterns that have equal edge hexagons and cover a surface without any gaps or overlaps (Friedenberg, 2019, & Kitrick, 2015). The distance of each hexagon was 5m² that represented the experience of personal space (Gifford, 1983) which reflects *"the emotionally tinged zone around the human body that people feel is their space"* (Iachini, 2017). The overlapping analysis was done for both set of polygons, before and after restrictions.

3.4.3. Spatial Distribution by sociodemographic characteristics (buffer visualization)

To answer the research question about the main differences in frequency according sociodemographic characteristics buffer visualization was calculated with the centroids of the drawn polygons by participants (figure 25 Annex). A buffer is a process to create one or more zones around selected features with a pre-specified distance (Longley et al., 2018) and was applied because it allows to visualize the main areas and spaces where participants have more interaction. Buffers were done with a Euclidian distance of 5 meters which is based on the personal space definition. (Maragakis, n.d.). Finally, a selection by sociodemographic attributes was applied to the buffer for each group (before and after restrictions).

3.4.4. Hotspot analysis

Hotspot analysis was developed in ArcGIS Pro using Getis-Ord Gi* statistics tool. Hot spot analysis facilitates the identification of spatial clusters of high values (hot spots) and low values (cold spots) (ESRI, n.d.c). It shows the higher concentration of events comparing to the expected number providing a random distribution of phenomena (Columbia Public Health, n.d.). All the values were displayed in maps for both components of the survey, before and after restrictions to identify the areas were participants had more interaction with the public spaces at Campus. Hotspot analysis identifies atypical locations in the spatial distributions, so its use can help to visualize the main groups or spatial relationships that could support the objective of inferring the changes in the spatial cognition of public spaces. The presence of atypical values guides can be used to show the main spatial clusters and outliers in the public spaces at study area.

3.4.5. Cluster analysis

Hierarchical cluster analysis was applied to identify the areas that are based on some similarity measure such as Euclidean distance (Jain et al., 1999; Jain et al. 2000 in Mahamed et al., 2007). The identification of the cluster groups helps to visualize if there is a pattern in the distribution of using public spaces at Campus of Campolide that could support the study of changes in spatial cognition. Identifying geographical areas in the study area can help to find some spatial relationships in the search of spatial cognition. Cluster analysis was done in ArcGIS Pro with to show the spatial distribution in the map. Cluster analysis is a multivariate analysis method that groups variables or elements with homogeneous characteristics which can help to show the differences during COVID-19 outbreak.

4. RESULTS AND DISCUSSION

4.1 Survey

4.1.1. Survey data

The survey was answered by a total of 47 participants that included students, professors and Staff from NOVA University Lisbon (Campolide Campus). The polygons drawn by the participants are in the following map from figure 4.1. It shows that for both questions there were some polygons that exceeded the study area, encompassing other public spaces close to the Campus of Campolide like "Amalia Rodrigues Garden" and "Eduardo VII park" that are green areas where people usually spent time for relaxing, doing exercise and social meetings.

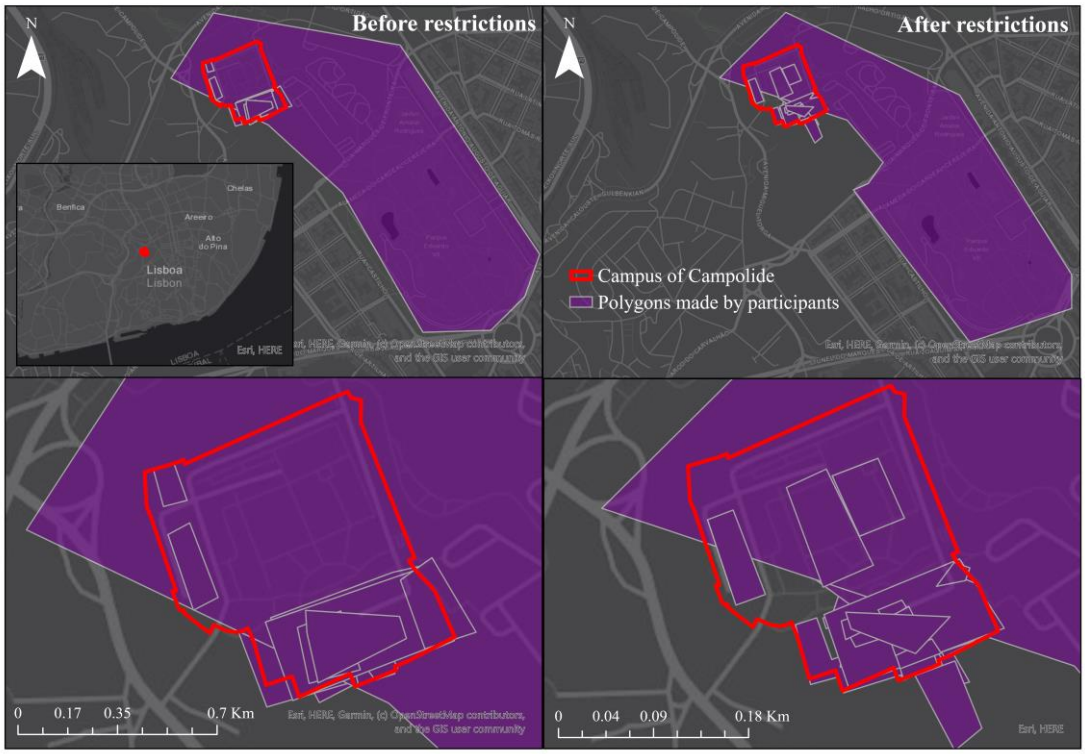

Figure 4.1. Polygons drawn by all the participants corresponding to before the and after restrictions questions.

The total of polygons counted for the before sections was 109 with one outside the study area. For the section after restrictions the total of polygons was of 66 with 2 outside the study area. As it was presented in the previous figure, for the first set of polygons (before restrictions) just one exceeded the dimension of the study area

representing 1%, while for the second group (after restrictions) there were two, representing 3%.

Polygons that were completely outside the study area were dropped out of the analysis because they did not give accurate information that could be used to answer the questions or achieve the objectives of the thesis. For the set of polygons drawn before restrictions the total number for the analysis was 108, while for the those drawn after restrictions the final count was 64. The final polygons were constraint to the study area (figure 4.2).

Figure 4.2. Final polygons for the analysis.

4.1.2. Sociodemographic characteristics

The main nationality of the people that answered the survey was Portuguese with a count of 34 participants that represented 72% of the total, while 28% came from other countries like Brazil, China, Greece, Nigeria, North Macedonia, Serbia, Sri Lanka, Swaziland, Uganda and USA. The age of participants was ranged between 18 to 60 years old, with the major proportion in the range from 18 to 25 (19 participants) that represented 68%. The attributes split the data into two main profiles that tried to consider the profession or job. The first one was from 18 to 35 years old that represented the main group of bachelor, master and PhD students with 81% (38

counts), while the second one from 35 to 60 was 19% (9 counts). According to the gender, 27 people were female (57%) and 19 were male (40%), with just one selection who preferred not to specify the answer (3%).

The table 4.1 shows the data on participants' educational level. The major proportion of participants corresponds to people that chose having a high School Diploma (44.6%), while the second most important group was people that answered having a Master's Degree (29.7%). Just one person skipped the answer of this question.

Educational level	**Count**	**Percentage**
No Degree	2	4.25%
High School Diploma	**21**	**44.68%**
Associate Degree or Certificate	0	0%
Bachelor's Degree	6	12.76%
Master's Degree	**14**	**29.78%**
Ph. D.	3	6.38
Other	0	0%
Skipped answer	1	2.12

Table 4.1. Count and percentage of the participants' educational level.

Regarding the main profession or job, 32 people were students (69%), 11 were professors, researchers and staff (23%) and 4 related to other professions (8%) like manager, executive, manager and physician.

4.1.3. Change in frequency and use of public spaces at NOVA Lisbon University (Campus of Campolide).

As a part of the thesis objective, this subsection shows the main results in the change on the frequency and use of public spaces at the study area that participants considered before and after pandemic restrictions. Regarding the questions about the time participants spent in the study area before and after pandemic restrictions (figure 4.3), people expressed a decrease in the number of hours being at the Campus. In the group from 6 to 9 hours there was a change from 51% before pandemic restrictions to 13%

after restrictions. Also, the group from 3 to 6 hours increased from 30% to 45%, indicating the average of time spent in the study area.

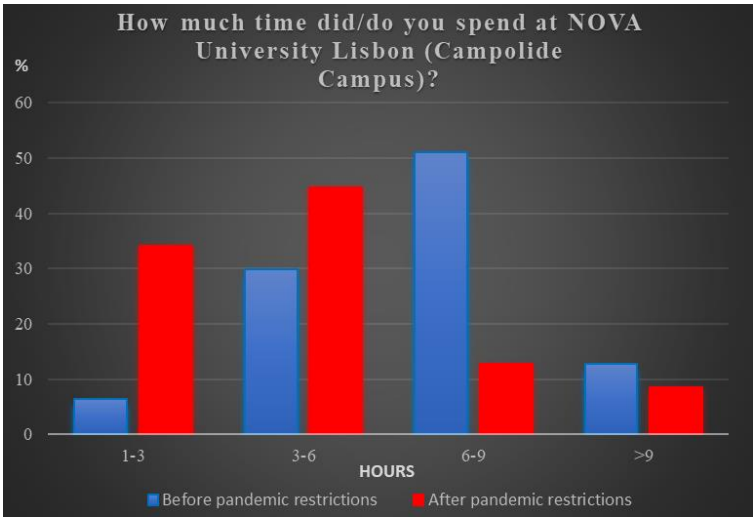

Figure 4.3. Results of question regarding time spent at NOVA University Lisbon before and after pandemic restrictions by percentage.

Related to the main activities performed in the public spaces in the Campus, participants could answer with multiple choice. Most of the activities like studying, spending time, having meals, meeting for tasks or projects and relaxing showed a change in the reduction of the frequency of 50% or more in representation, while working and having classes did not implied a major difference (figure 4.4).

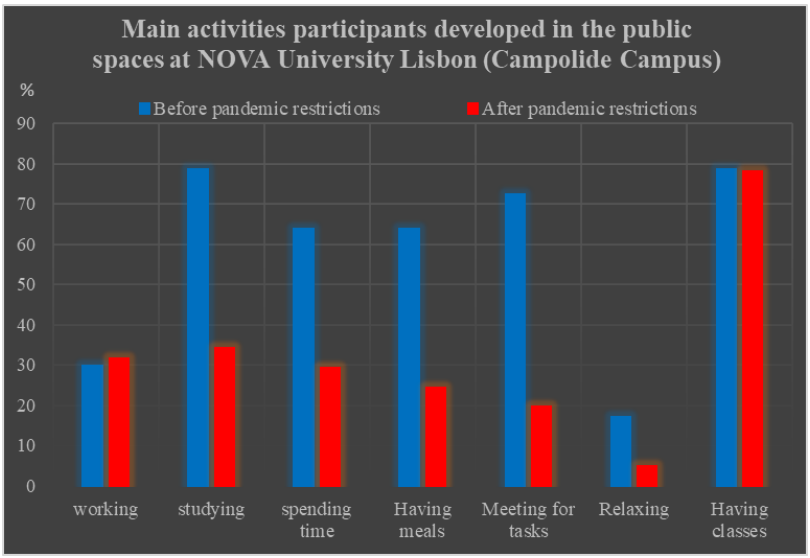

Figure 4.4. Results of question regarding main activities participants developed in the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

Another result presented a change in the frequency of public spaces in the Campus (figure 4.5) during the morning, afternoon and evening. As this question had the option of multiple choice, participants could select more than one option. The frequency of people using public spaces during the morning decreased from 72% before restrictions to 15% after restrictions, there was an increase in the afternoon (81% to 95%) and there was a decrease int the night (43% to 32%).

Finally, people considered that they had a change in the frequency of visiting public spaces at Campus (figure 4.6). Participants significantly decreased the attendance everyday (from 26% to 2%) as every weekday (from 47% to 12%). In contrast, there was an increase in the frequency of two weeks or more that represented a change from 4% to 64%.

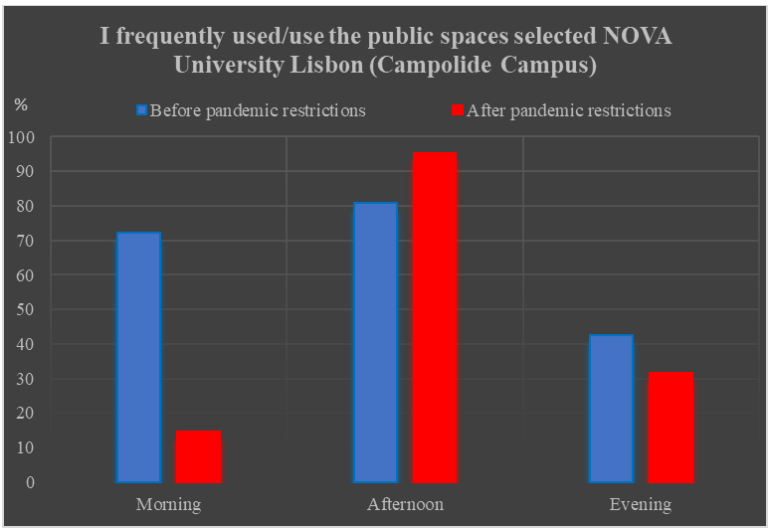

Figure 4.5. Results of the question "I frequently used/use the public spaces at NOVA University Lisbon (Campolide Campus) in the morning, afternoon and evening before and after pandemic restrictions" by percentage.

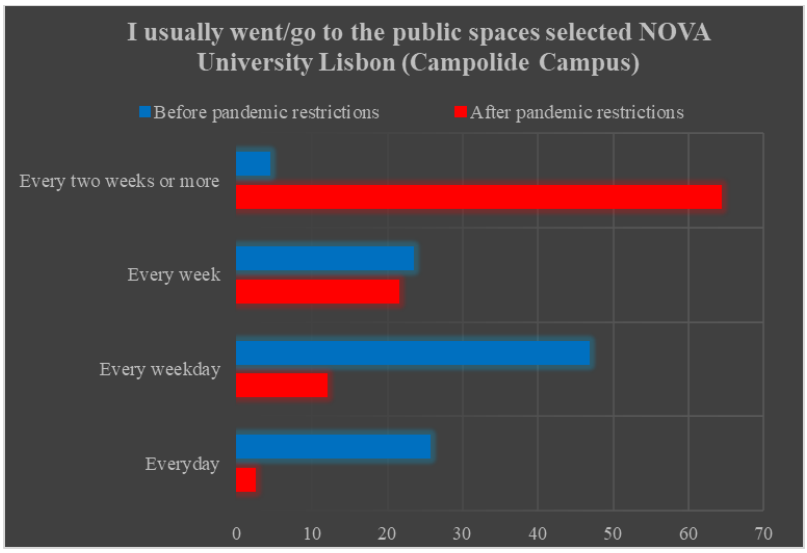

Figure 4.6. Results of the question "I usually went/go to the public spaces selected at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions" by percentage.

4.2 Overlapping analysis

The overlay analysis presents the frequency of drawn polygons by participant in each section that corresponds to before and after restrictions. These results contribute to achieve the objective of present the frequency in the use of public spaces at the study area during the COVID-19 outbreak. Figure 4.7 shows the main changes related to the use of public spaces at the Campus. The study room located close to Alfredo de Sousa Residence had a minimum frequency before pandemic restrictions, but after restrictions this area did not show any intensity. Alfredo de Sousa Residence also suffered a decrease in the intensity of use. Public spaces before pandemic restrictions showed a high intensity close to NOVA IMS building, presenting high values located in the cafeteria, library and the study room nearby. After pandemic restrictions the mentioned areas suffered a decrease in the intensity of use due to restrictions settled by university. The central area that keeps high values in both maps corresponds to an open public space that is frequently used as a meeting point where students, professors and staff can spend time to have a break, talk with friends, have lunch or other activities. In the 24 hours study room, Eramus Mundus Room and the Cantine close to this area there was also a decrease in the intensity of use after restrictions. Finally, the

violet color in the center of the campus show an increase in the frequency of visiting green areas of the Campus.

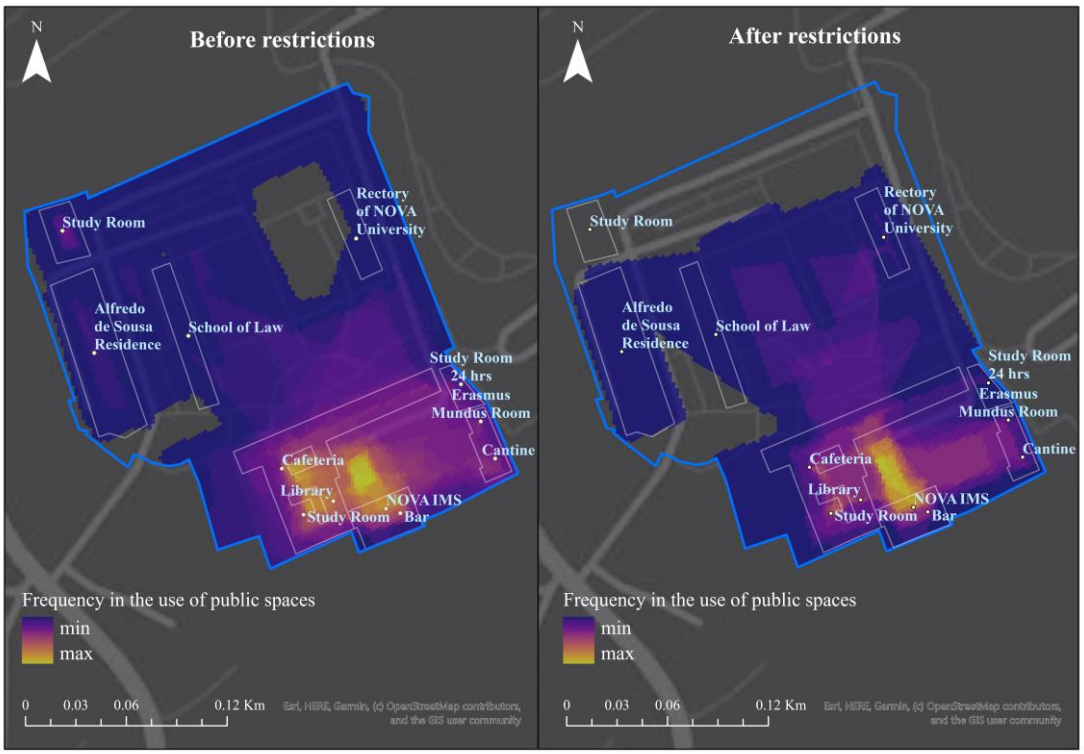

Figure 4.7. Overlay analysis.

4.3 Spatial distribution by sociodemographic characteristics (buffer representation)

The following maps show the spatial distribution of the buffers applied to the centroids of the polygons made by participants according to sociodemographic characteristics like gender, age, educational level and profession or job to search for patterns in the participation of people. The results presented contribute to identify the participants' main areas of influence according to sociodemographic characteristics.

4.3.1. Gender

Figure 4.8 shows the distribution of the buffer analysis applied to the centroids according to the gender of participants. The female gender presented a decrease in the frequency of public spaces like study rooms that changed after pandemic restrictions. The intensity of visiting public spaces close to NOVA IMS is evident for female

gender in both periods of time. The distribution by male gender shows a decrease in the use of different public spaces like the study room located in the Northwest, the "Alfredo de Sousa", the school of law and the study rooms located close to the Erasmus Mundus Room.

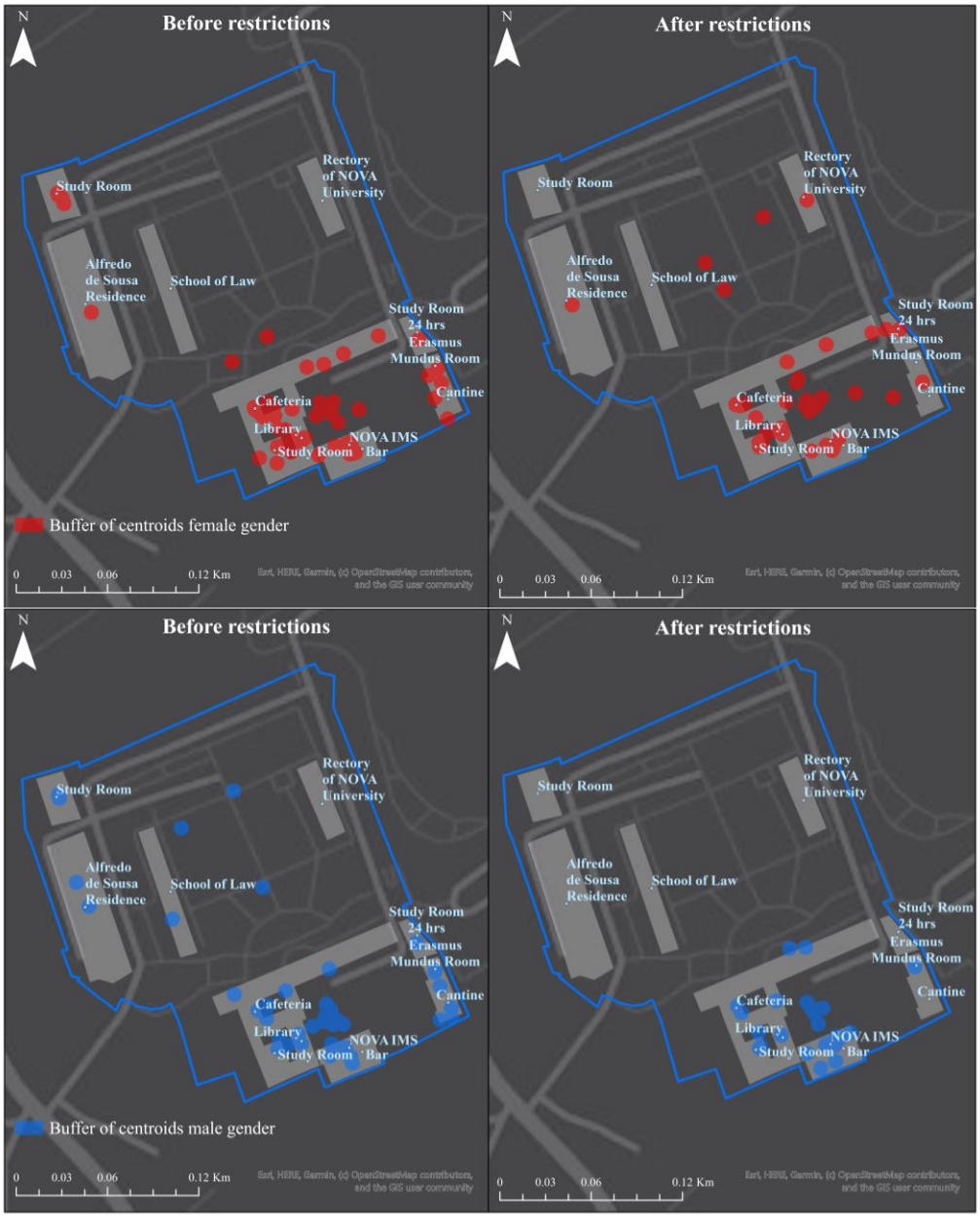

Figure 4.8. Buffer visualization by gender

4.3.2. Age

The distribution by the group of age from 18 to 35 years old represented the majority of the participants showed in the map (figure 4.9). As this group represents mainly students there is a decrease in the use of specific areas like "Alfredo de Sousa" Residence and public spaces like the NOVA IMS Cafeteria, Library and Student Room nearby. The distribution by the range from 36 to 60 years old showed a distribution just focused in the public spaces of NOVA IMS like the cafeteria, library and offices located in this region of the Campus that could be related to other activities like working and relevance of other professions. There is a decrease in the participation of open public spaces that could evidence the restrictions implemented after the outbreak as a measure to decrease and prevent the contagion of the illness.

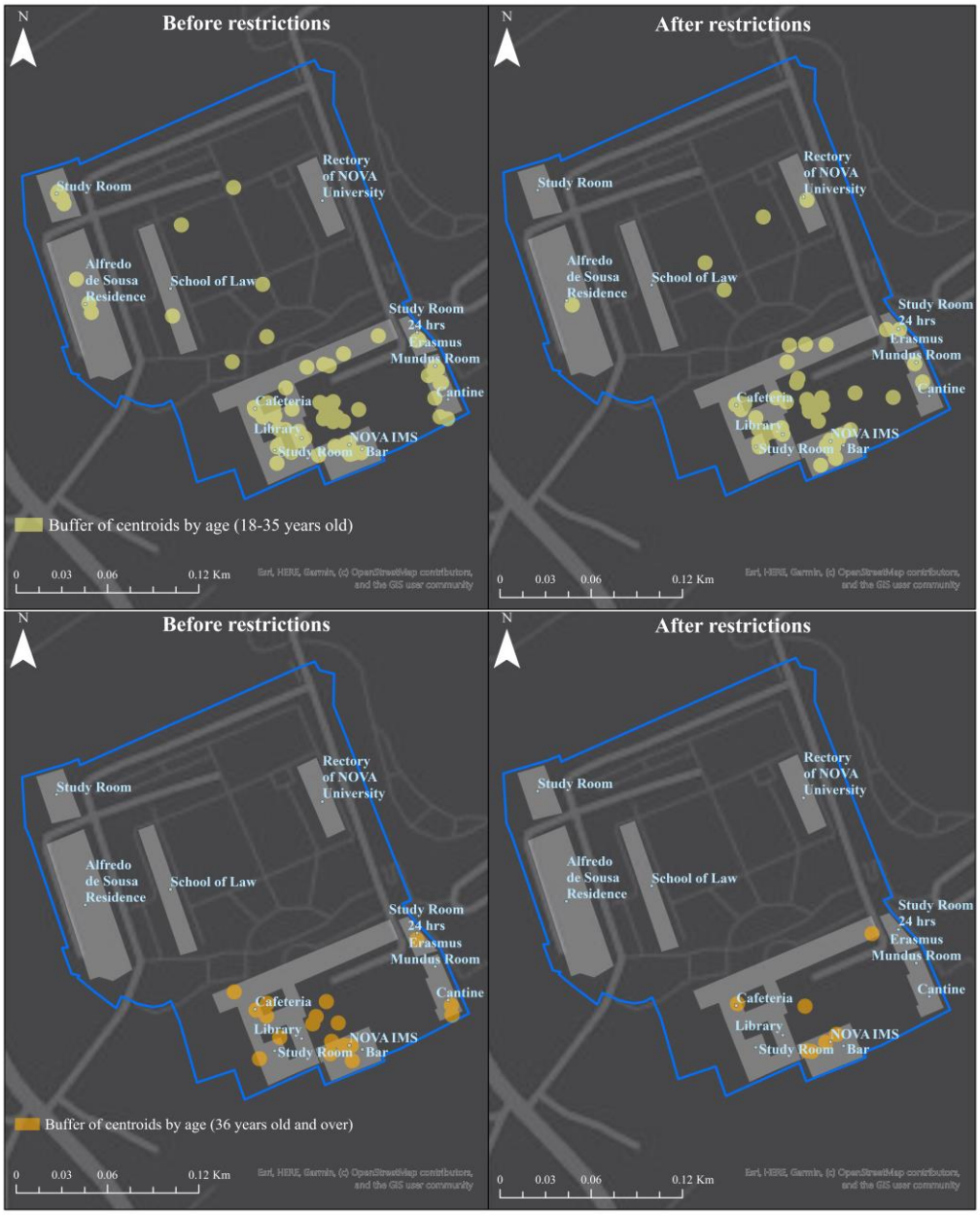

Figure 4.9. Buffer visualization by group of age

4.3.3 Educational level

The distribution of buffer selecting participants with no degree show a centralized concentration in the public spaces close to NOVA IMS building (figure 4.10). This selected buffer just presented few differences in the study room located close to Alfredo de Sousa residence and the 24 hrs study room. The buffer of participants with high diploma level showed changes in areas like the study room close to Alfredo de Sousa residence and a major dispersion after pandemic restrictions.

Regarding the distribution by participants with bachelor degree (figure 4.11) there was a reduction in the use of areas like the study room close to the residence, the Alfredo de Sousa residence, the school of Law and the study rooms located close to the Erasmus Mundus Room. The participants with master's degree also showed a change in the distribution in public spaces like the study room close to the residence and the decrease of concentration of the use of public spaces close to NOVA IMS building. The buffer selection with PhD (figure 4.12) showed a decreased in the frequency of public spaces before and after the pandemic restrictions. This group was just attached to the NOVA IMS area.

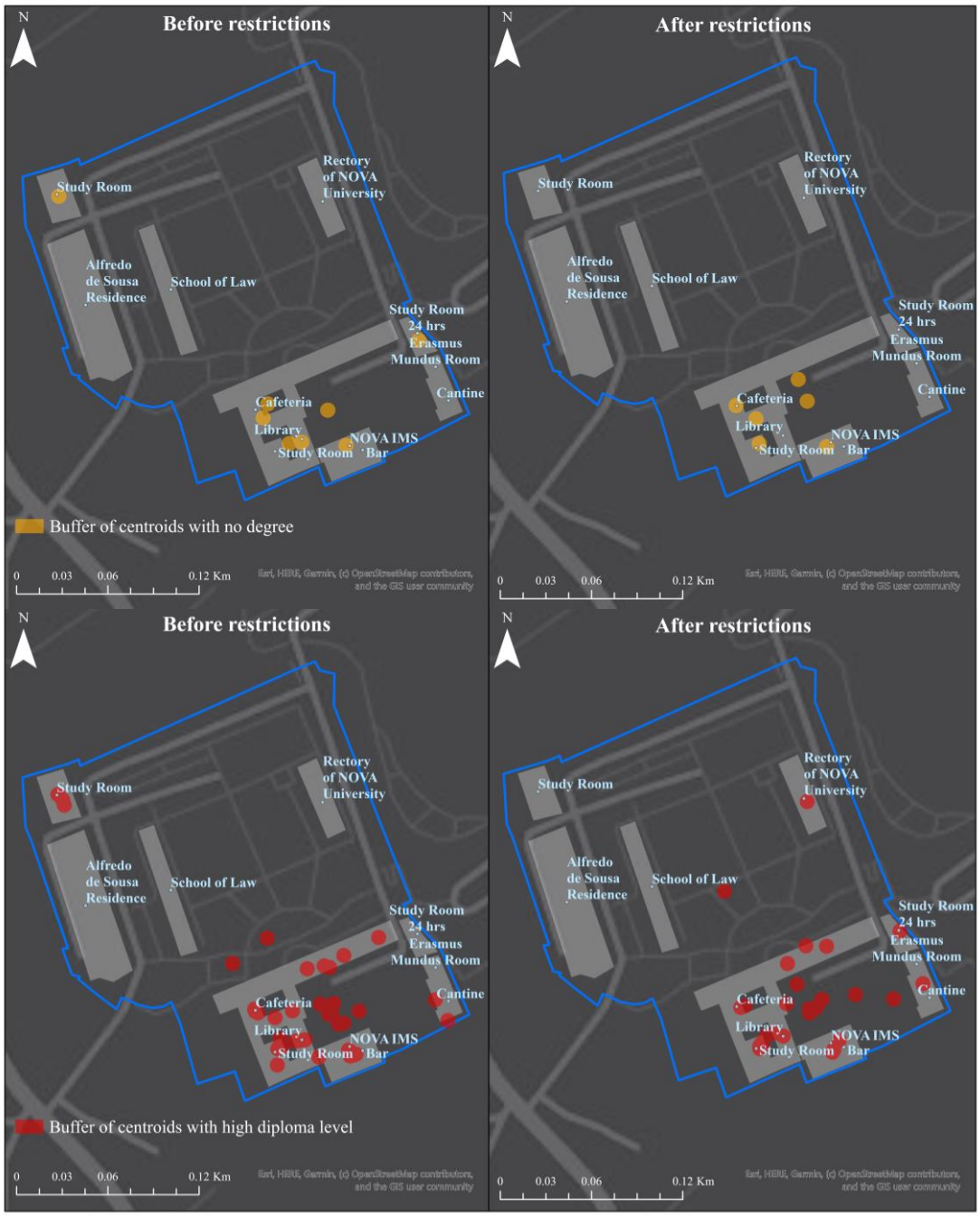

Figure 4.10. Buffer visualization by educational level (no degree and high diploma level)

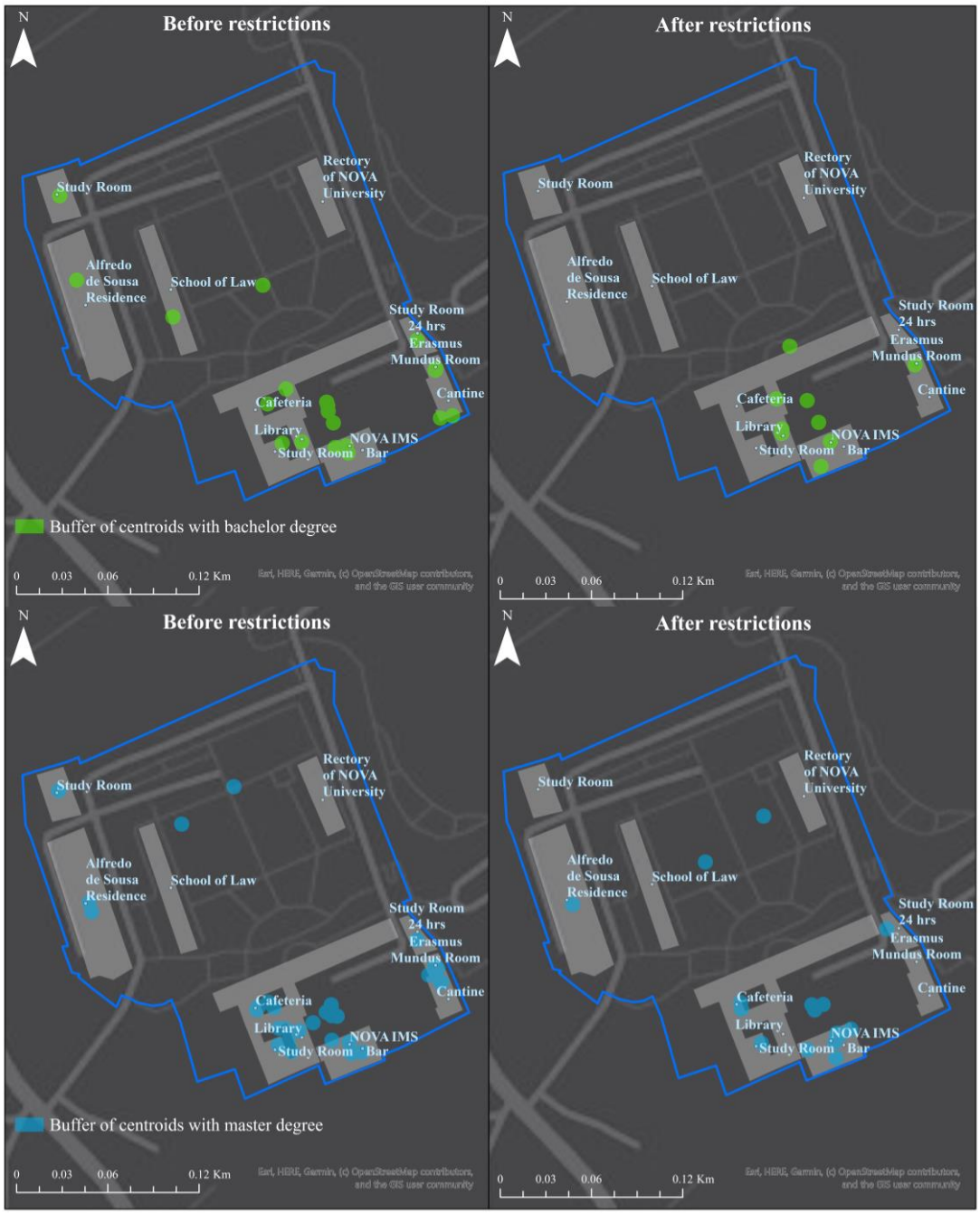

Figure 4.11. Buffer visualization by educational level (bachelor degree and master degree)

Figure 4.12. Buffer visualization by educational level (PhD)

4.3.4. Profession or job

The group of students (figure 4.13) represented the proportional majority in the profession or job, showing a spatial dispersion before pandemic restrictions. The areas that show a change were the study room close to the residence, the "Alfredo de Sousa" residence, and the School of law. Also it is evident a major spatial distribution in the open central area close to NOVA IMS building due to the higher concentration of points. Regarding the distribution by professors (figure 4.13) there is also a decrease in the frequency and intensity of public spaces specially those close to NOVA IMS building. Finally, the distribution by other professions (figure 4.14) show more dispersion after pandemic restrictions.

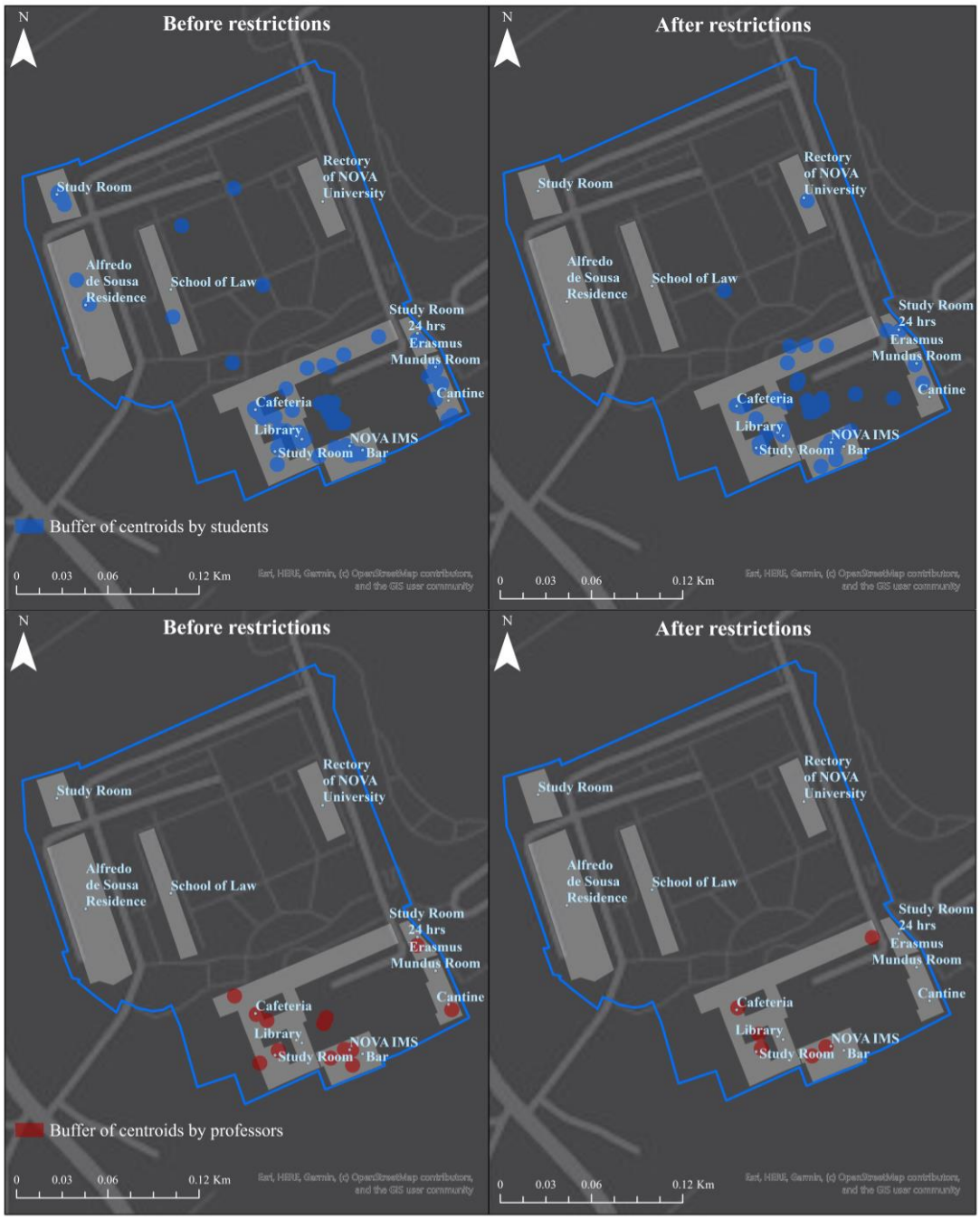

Figure 4.13. Buffer visualization by profession (students and professors)

Figure 4.14. Buffer visualziation by other professions

4.4 Hotspot analysis

The following map (figure 4.15) shows the results of hotspot analysis before and after pandemic restrictions. The areas with cold spots are located in the north of the Campus, in public spaces like the Residence, the School of Law and the central green spaces. The concentration of the Hotspots is in the areas where students usually have more activities like the Cafeteria, Library and the main building of NOVA IMS. There is a change in the extension of the hotspots, being smaller after pandemic restrictions and with a pattern oriented to the East of the Campus related to the open public space used as a meeting point.

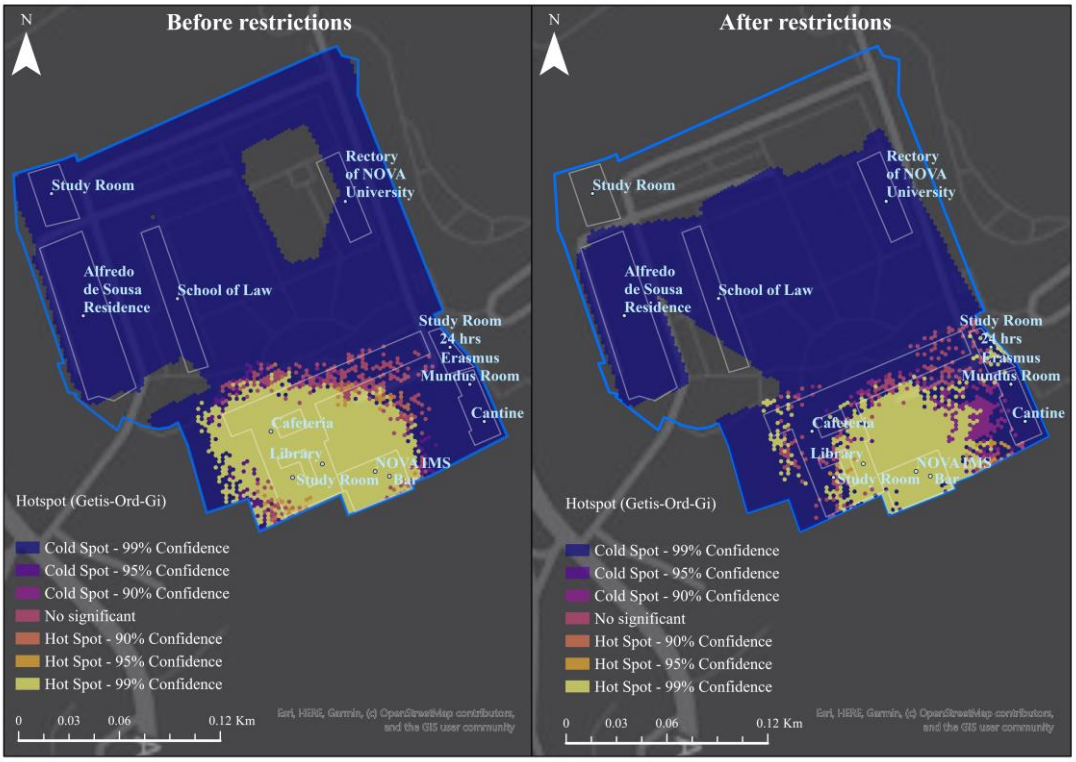

Figure 4.15. Hotspot analysis before and after restrictions

4.5 Cluster analysis

The cluster analysis in figure 4.16 shows the delimitation of areas that participants drawn related to public spaces. Cluster 3 before restrictions represents the major area corresponding to the green spaces of the Campus. Clusters 2,3,4 and 5 are centralized in NOVA IMS building. After pandemic restrictions the cluster analysis show no covered areas, which represents the decrease in the use of public spaces like the study room close to the residence. Also, after restrictions there was an evident concentration to the open area close to NOVA IMS showed in the cluster 5. The group of classrooms close to Erasmus Mundus Room represents a new cluster number 5 that is associated to the lowest values.

Figure 4.16. Cluster analysis before and after restrictions

4.6 Perception results

The survey also tried to identify the main changes in the perception that participants had in the use and frequency of public spaces during the pandemic situation. As part of the survey, people had the option to provide one or more words that described their relationship with the public spaces at NOVA Lisbon University (Campus of Campolide) before and after restrictions. Before restrictions many comments, thoughts and opinions were oriented to ideas that described a positive perception about the Campus and the spaces. Also, many people answered that they really enjoyed spending time there to do different activities like studying, talking and meeting with friends. Students mentioned that usually visited public spaces to do the assignments, homework, reading and other activities related to studying.

In order to simplify the main ideas, the word cloud of the figure 4.17 shows the main words that people had according to the social interactions as well with the public spaces in the Campus.

Figure 4.17. Word cloud related to feelings, perceptions and experiences' participants had in the study area before pandemic restrictions

According to people's perception after restrictions (figure 4.18) there was a change that was more focused to show the current situation of the pandemic produced by COVID-19. The group of ideas and opinions that people described about their social interactions were focused to express a negative experience where they cannot gather and see their friends as much as it was before the restrictions. Other ideas were focused to describe feelings like sadness, stress, loneliness and depression. The ideas focused on showing the relationships with the public spaces were the lack of the involving environment, the reduction in the frequency of classes in presence as well as the increase of online activities and tasks. Another change in the perception of people about the public spaces at the Campus were oriented to describe them as point of risk of contagion and the loose of their identity comparing them more to a building than a space where they can develop their activities.

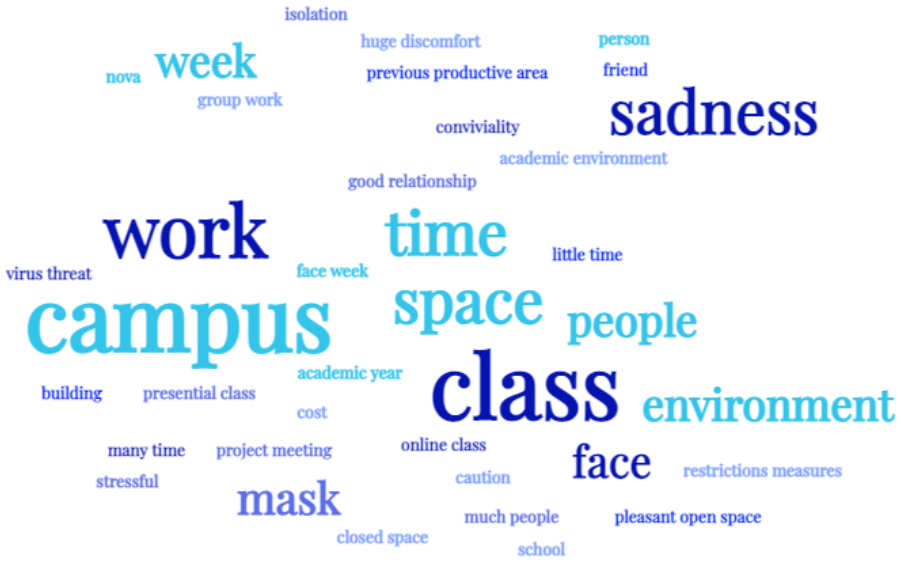

Figure 4.18. Word cloud related to feelings, perceptions and experiences' participants had in the study area before pandemic restrictions

As a part of the thesis, the survey also included a section that tried to frame the change in the perception of public spaces in the study area using a Likert scale. According to the opinion of participants there was a change in the frequency of visiting public spaces before and after restrictions (figure 4.19). The main differences about the perception of spending time in the public spaces where in the cafeteria (decrease from 26% to 7%), the classrooms (decrease of strongly agree from 18% to 6%). People considered a neutral position to the corridors after restrictions. Participants do not consider a change in the frequency of spending time after restrictions in public spaces like natural areas, benches, library, offices and classrooms.

Regarding the perception of security and safeness (figure 4.20) people answered that they had a neutral opinion in most of the public spaces, especially in the offices, library, study rooms, canteen and cafeteria. In other places like classrooms, benches and natural areas they considered a feeling of security which is associated with more open spaces and dispersion of people.

Regarding the perception of enjoying public spaces at the Campus (figure 4.21) there was an evident change of perception in places like the cafeteria, canteen, study rooms offices and corridors, while in the case of natural areas, benches, library and classrooms there was a neutral opinion.

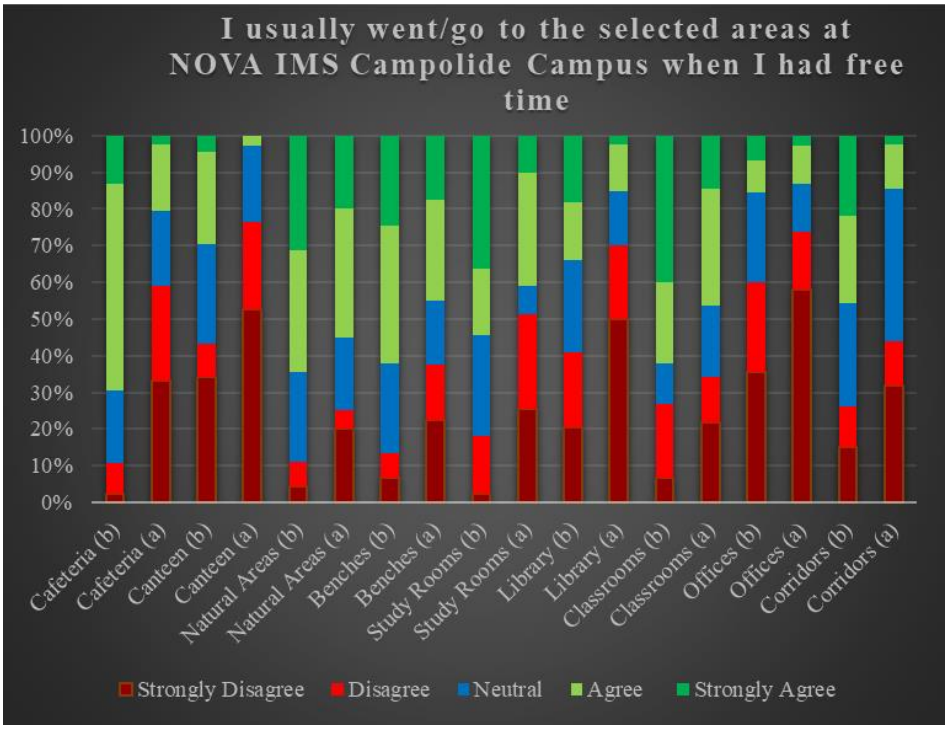

Figure 4.19 Results of question regarding main activities participants developed in the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

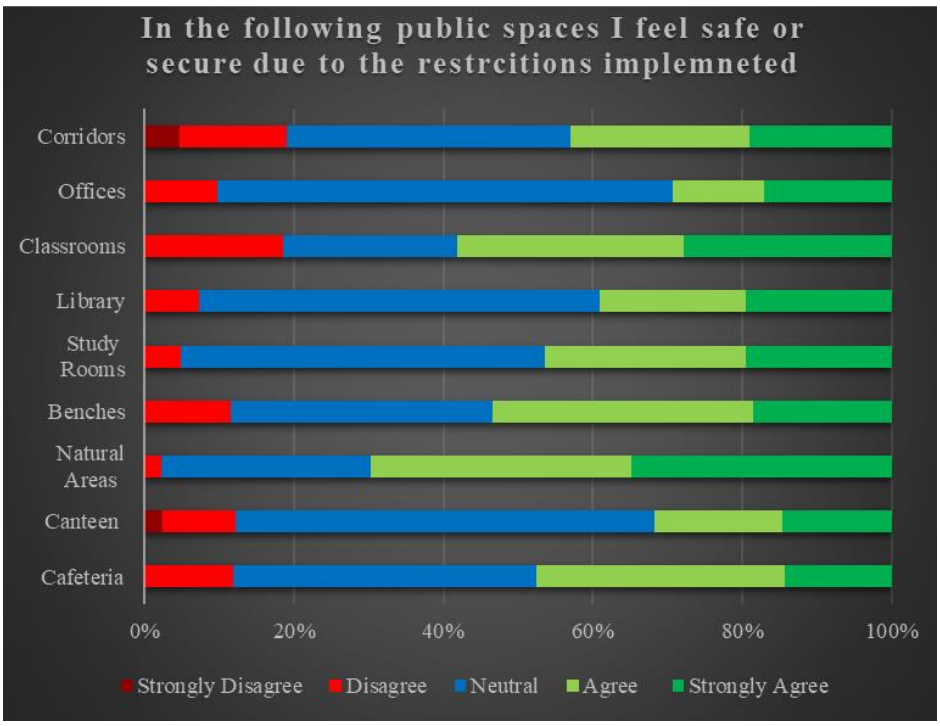

Figure 4.20 Perception of security and safeness in the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

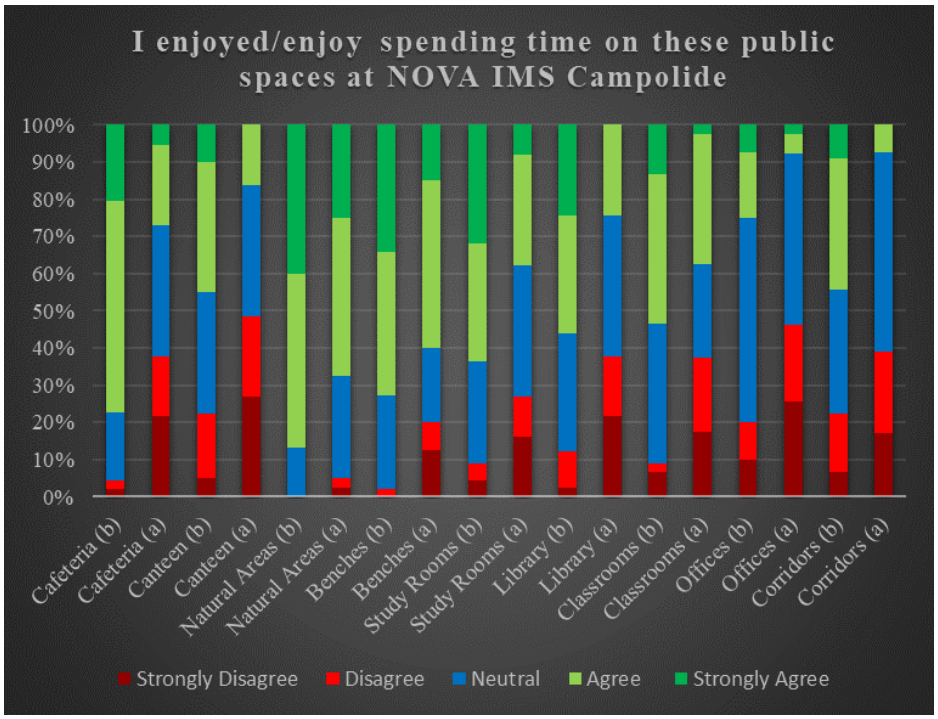

Figure 4.21 Perception of enjoying the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

The perception of activities done by participants (figure 4.22) shows a major change in activities like relaxing, meeting for projects, spending time with friends and studying no change in other activities like working. This means that people have tried to continue working in the study area. As mention before, the activities of relaxing, meeting for projects and spending time with friends have been reduced in order to follow the university regulations.

Regarding the people's opinion about the preference of staying at home as much as possible until the pandemic situation finishes (figure 4.23) the main results show that there are participants that agreed with the sentence and other that disagree, so there are two main groups of opinion in this question. Most part of people surveyed expressed that they preferred having presential classes. Also, the majority of participants think that even with more restricted measures in the public spaces they would not use them. Many participants expressed that they feel stressed using public spaces at the Campus because these were linked to spaces of contagion.

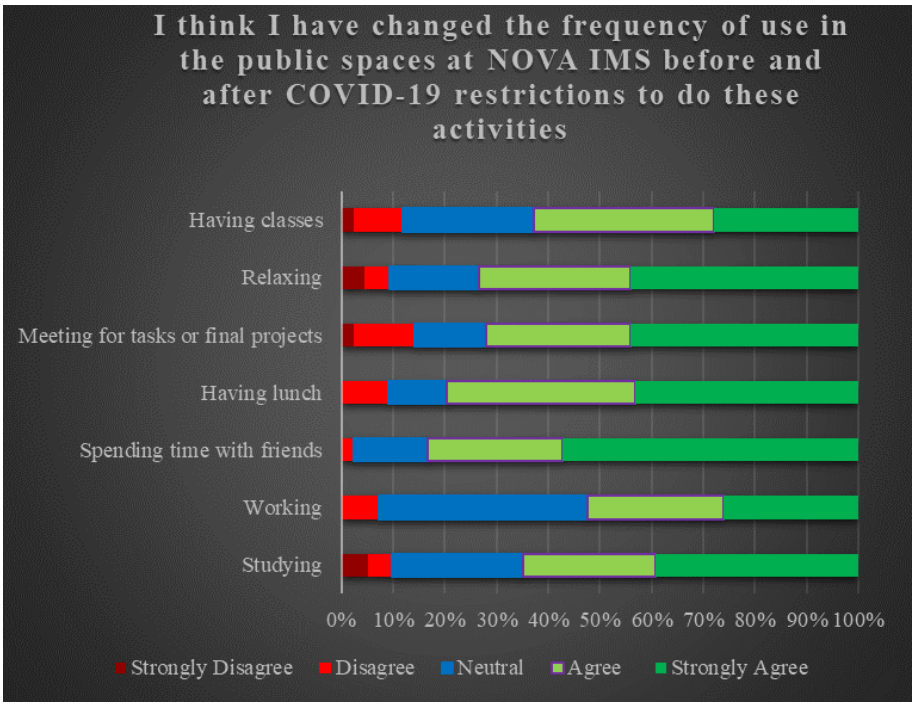

Figure 4.22. Results of question regarding main activities participants developed in the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

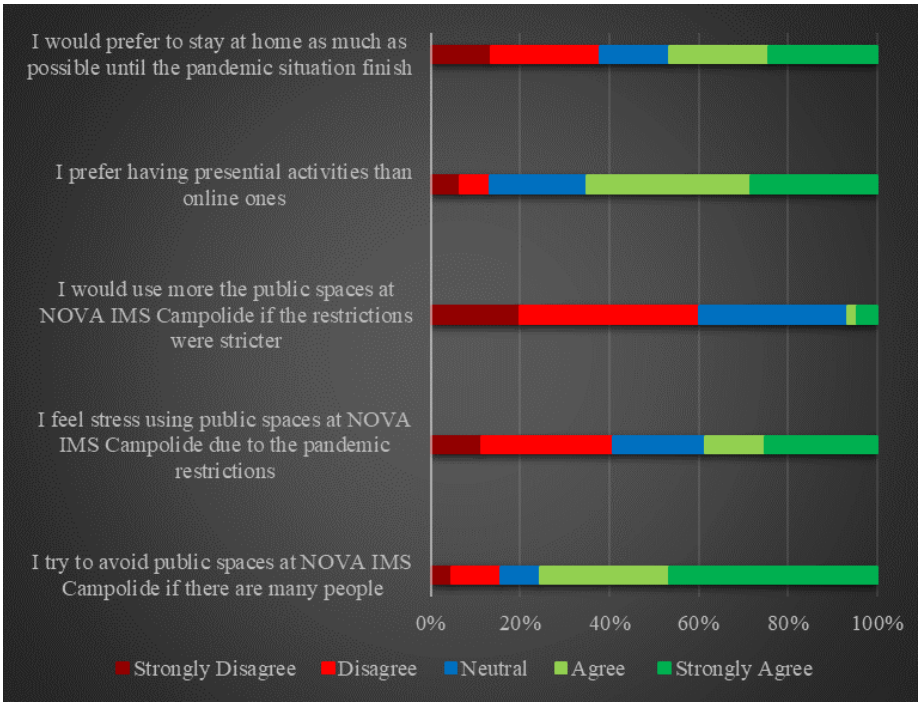

Figure 4.23. Results of question regarding restrictions in the public spaces at NOVA University Lisbon (Campolide Campus) before and after pandemic restrictions by percentage.

5. FINAL DISCUSSION

The changes in the frequency of visiting public spaces at NOVA University Lisbon Campolide Campus showed main differences related to the limitation and restrictions of specific areas like classrooms and study rooms. The study room located close to Alfredo de Sousa residence presented main changes in the frequency of use reported by the overlapping and sociodemographic results. These changes were product of measures about reducing the number of public spaces and people that could represent a risk in the increase of contagion. Before pandemic restrictions, this study room was constantly visited by many students, especially previous to final exams and projects, so as it represented a big area of concentration of people, the university denied the access to it during the pandemic outbreak.

Alfredo de Sousa Residence had a decrease in the frequency that was product of policies like the reduction in the capacity of the residence and the exclusive access to them. Other restrictions were the closure of common areas inside the residence like study rooms and kitchens. This area before pandemic restrictions was used as a meeting point with the possibility of doing many activities like yoga, playing a game, gathering for final projects and reading in the study rooms, showing significant changes during COVID-19 pandemic.

NOVA IMS area that included many public spaces like the cafeteria, the library, study rooms, classrooms, benches and open spaces presented slightly changes that were associated by the measures of the University. The main restrictions applied to these public spaces were the mandatory use of mask inside them, the constant hand washing and the check-in of presence in classrooms, study rooms and the library before entering. The main results in frequency of these public spaces also showed the increase of online classes and the reduction of presential activities. Another evident change in the frequency of the public spaces at NOVA IMS were in the study room, Erasmus room and Canteen because they also were closed after pandemic restrictions.

The frequency of public spaces by sociodemographic characteristics showed some spatial differences. One of these differences was the concentration and dispersion in the frequency according to the age, gender and profession. The main representation in

the results was by the group of students, which were the majority. The distribution of the buffer visualization showed a major density of the female gender. As in the case of students, the group from 18 to 35 years old implied the major concentration in the public spaces, specially those at NOVA IMS area.

Another evident change was the public space in the center of NOVA IMS, which is an open space that has many tables and benches used by the students, professors and staff for different activities like doing homework, relaxing, spending time with friends and waiting for the next class. This area showed an increase in its frequency after pandemic outbreak because represented an open space with no concentration of people and where it was possible to have free time to relax.

The perception of participants during COVID-19 pandemic has showed that most of the participants considered to have change in the use of public spaces at university, especially because of the increase of online activities. Participants exposed that they preferred to have presential classes but once the pandemic situation improves. Half of the participants considered that there was not a change in the feeling of security produced by the measures implemented by the university like the mandatory use of mask and the constant application of alcohol in gel.

Participants' opinion also showed differences in the conception of public spaces before and after restrictions. Before pandemic outbreak people expressed ideas that were related with feelings that described their interactions to the university such as a space where they could feel free, happy and a general perception of enjoying academic activities at university. Some public spaces like the cafeteria, 24hrs study room, corridors and NOVA IMS library where the public spaces mentioned by participants as areas where they could perform their activities with no stress and any concern. Also, participants expressed having more social dynamism that helped to do the different tasks, exams and projects from the university. Before pandemic restrictions participants showed a general perception about having a relationship with the public spaces at the university.

The perception of participants about public spaces at the study area changed after pandemic restrictions were more focused to remark the stress produced by the health crisis, the closure of some public spaces (study rooms) and the limitation to their access

(classrooms, canteen and cafeteria). Another change in the perception of participants after pandemic outbreak was the emphasis of associating many public spaces with buildings or physical areas with no connection to the perception of space where many activities could be developed. During the research, another change in the perception was the recognition and use of public spaces after the restrictions. As many students, professors and staff could not use them they evidenced their decrease and limitation. The general change in then perception of participants was the decrease in the feeling of belonging to the public spaces that were the result of the new restrictions and the increase of virtual activities.

Perceptions related to the time spent in the public spaces showed that students changed their routine in order to use them just for mandatory activities like having classes or the presentation of projects. Professors and staff did not show relevant changes in the perception of public spaces, so it could indicate the continuity of academic and labor activities. Results indicate that the main perceptions to public spaces were associated to the frequency, to the number of people using them and the stressed produced by the COVID-19 pandemic.

The main changes in the spatial cognition of public spaces at the study area were the differences in the conception of these spaces that was product of the restrictions and the interaction that participants had with them. The closure of some public spaces like the study rooms and the reduction in the use of others produced new cognitive relationships that impacted in the frequency and social constructions identified by the participants. The public spaces studied had a change in the spatial cognition of participants from areas where people could develop activities like studying, doing tasks and preparing projects to areas of caution and restrictions where just academic activities were allowed.

The constant regulations and measures implemented had an influence in the construction of the participants' spatial cognition that changed their perception from safe places to areas of risk of contagion where social interactions were limited and restricted. The concept of safeness had an impact in the change of spatial cognition related to the public spaces analyzed that could be identified in the increase of frequency of open and green areas as spaces of low risk of contagion. On the other

hand, the main changes in the spatial cognition that increased the concept of risky areas included classrooms and spaces with high density of people such as study rooms and the cafeteria.

6. Conclusions

The participation of professors, students and staff showed the way how they perceive and have changed the use of public spaces at NOVA University Lisbon during COVID-19 outbreak. The main objectives of the thesis were achieved showing the main results that presented the changes in the frequency, perception and spatial cognition of public spaces. The study of the frequency in the use of public spaces and the perception of people about the study area remarked the changes produced during COVID-19 health crisis.

The main changes presented in the study area were the frequency and perception of participants that showed different patterns of distribution that included the decrease in the intensity of the maps from before restrictions to after restrictions. Other differences presented focused in sociodemographic characteristics like age, profession, gender and educational level in order to identify the main patterns pf distribution expressed by participants.

The complexity of the study of spatial cognition showed an evident need of continuing the research on this area in relation to the pandemic situation. The different measures and restrictions implemented also impacted in the interpretation of results that were analyzed in the thesis. The evolution of the spatial cognition produced by the pandemic situation has evidenced new patterns in the use and perception of the public spaces analyzed in the study by students, staff and professors.

To frame the main differences produced by the COVID-19 in the public spaces at the study area it was necessary to include complex mental process that required the integration of all the information produced. Deeper analysis in the study of spatial cognition is fundamental in the acquisition of results.

The analysis could frame the base to understand spatial relations regarding the spatial cognition and perception analysis of students, professors and staff. The comparison before and after pandemic restrictions provided a different way to study the changes during the analysis. The results obtained can help to continue the analysis of COVID-19 and the spatial effects with support of GIS and perception.

6.1 Limitations

The first limitation was the lack of bibliographic references that included the concepts and elements studied in the thesis because of the recency of the pandemic outbreak. Although there have been many papers regarding the study of COVID-19 in different study areas, the productivity related to the mentioned elements has been quite short. The main papers found were those related to changes in spatial cognition due to the virus but with a medical focus. Many of the papers related to GIS and COVID-19 tried to explain and show the different techniques and geoprocessing tools to analyze the distribution and spread of the illness.

The second limitation of the study was related to the specification of participants. In order to achieve the goals of the thesis and show the changes in the use of public spaces, it was mandatory to constraint the participation of people to those who have been studying, working, or developing any activity in the Campus before and after pandemic restrictions. People like first year students could not participate for the sample of the analysis.

The third limitation was the application and collection of the data. The restrictions implemented by the University like the reduction of presential classes or the limitation in the use of many public spaces produced some complications that were solved by the support of University members like professors, PhD students and staff helping in the diffusion and cooperation for applying the survey.

Other limitations were related to the technical characteristics of the platform used for applying the survey, because although it was possible to draw many polygons, there were some issues like the sensibility of drawing that could interfere with the final results. Finally, there were some conceptual and structural limitations about the design of the survey. Some concepts like public spaces and perception could be vague for some participants.

6.2 Further analysis

Further work can include new theoretical framework related to the study of changes in the spatial perception and cognition due to COVID-19 like the impacts in the use of public spaces, restrictions, and new ways to interact with them. Regarding the design

and structure of the survey it could include more perceptional questions where participants can express their opinion and thoughts about the frequency, experiences and memories that can contribute the knowledge of the topic. For the processing of the information other analysis can be applied. Some quantitative variables can be added to show multiple results that include quantitative and qualitative data.

The inclusion of more participants with different age, profession, educational levels and other sociodemographic characteristics can enrich the work as well as the use of more interaction with tools where people could describe with more detail their experiences related to the public spaces at the Campus. The application of the thesis can be applied for future work to show the differences and similarities in the spatial behavior and cognition of participants that could give the base to explain other spaces. Finally, future work can be considered to implement new measures in order to prevent and reduce the contagion of the illness.

Further analysis also can include the main effects that the pandemic crisis has produced in the use of public spaces oriented to social relationships. Once the restrictions change in order to retake presential activities at university it could be possible to consider the main consequences that the outbreak produced in the perception of students, professors and staff.

Finally, further analysis for this type of study should include the continuity and developing of GIS and spatial technologies that can collect and process information from different sources like surveys and checkpoints. The use of GIS and geospatial elements can continue in the development of applications and analysis that process people's opinions and perceptions. Further work can contribute to search more projects oriented to spatial behavior, offering alternatives to the design of methodologies and applications.

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ANNEXES

Figure 1. Introduction of the survey

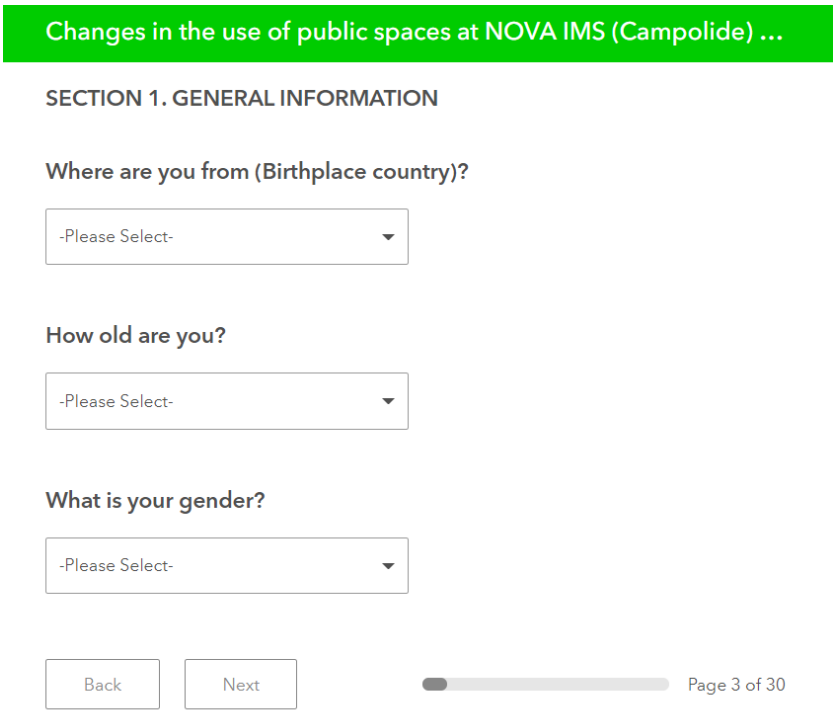

Figure 2. First group of questions from section 1 about General Information

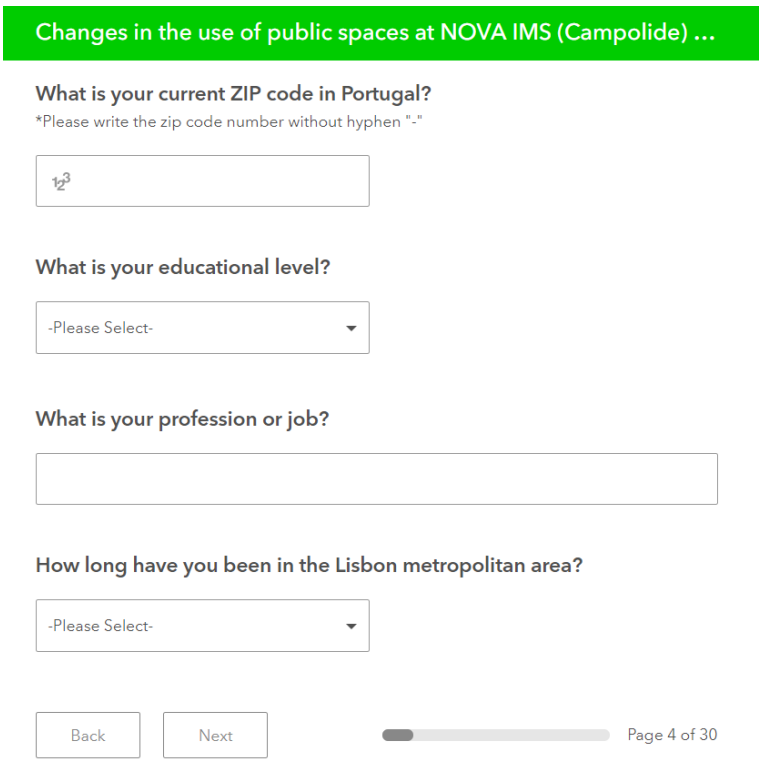

Figure 3. Second group of questions from section 1 about General Information

.

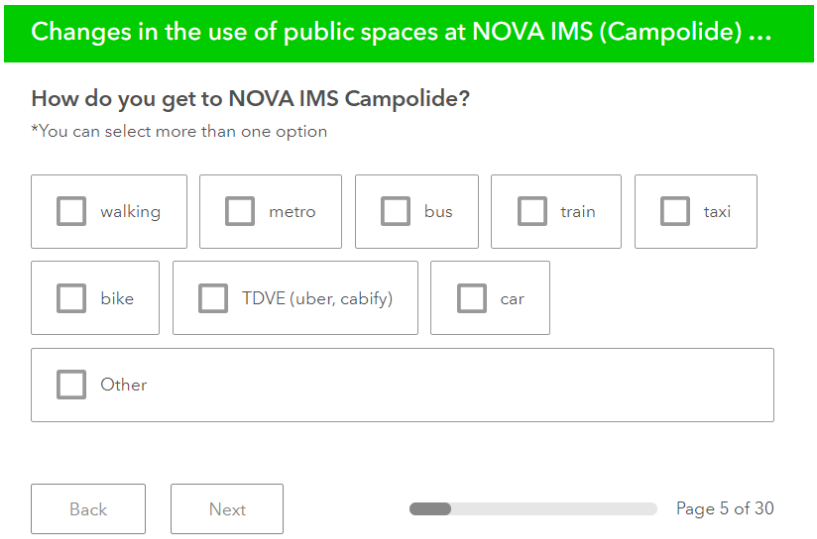

Figure 4. Question regarding the mean of transport to get the Campus

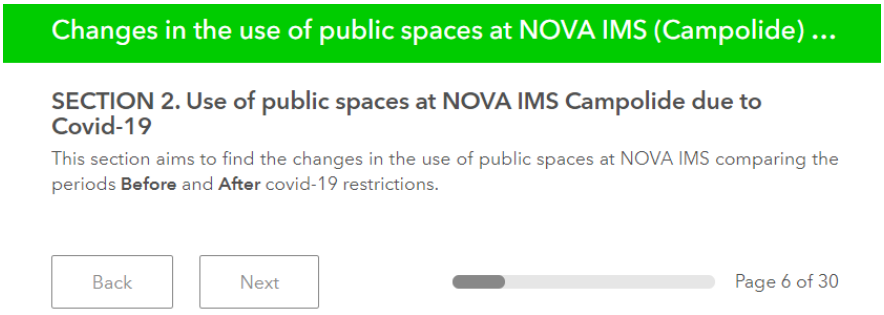

Figure 5. Presentation to section 2 Use of public spaces at Campus

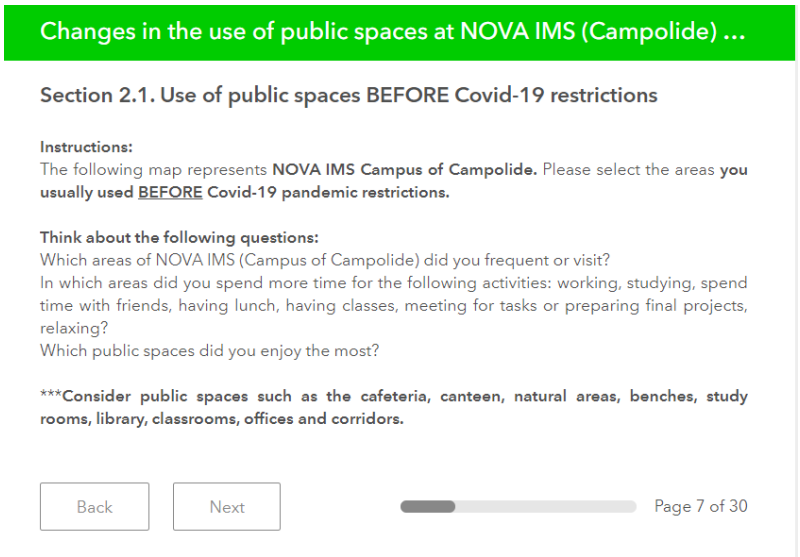

Figure 6. Instructions of section 2.1 Use of public spaces at Campus before COVID-19 restrictions

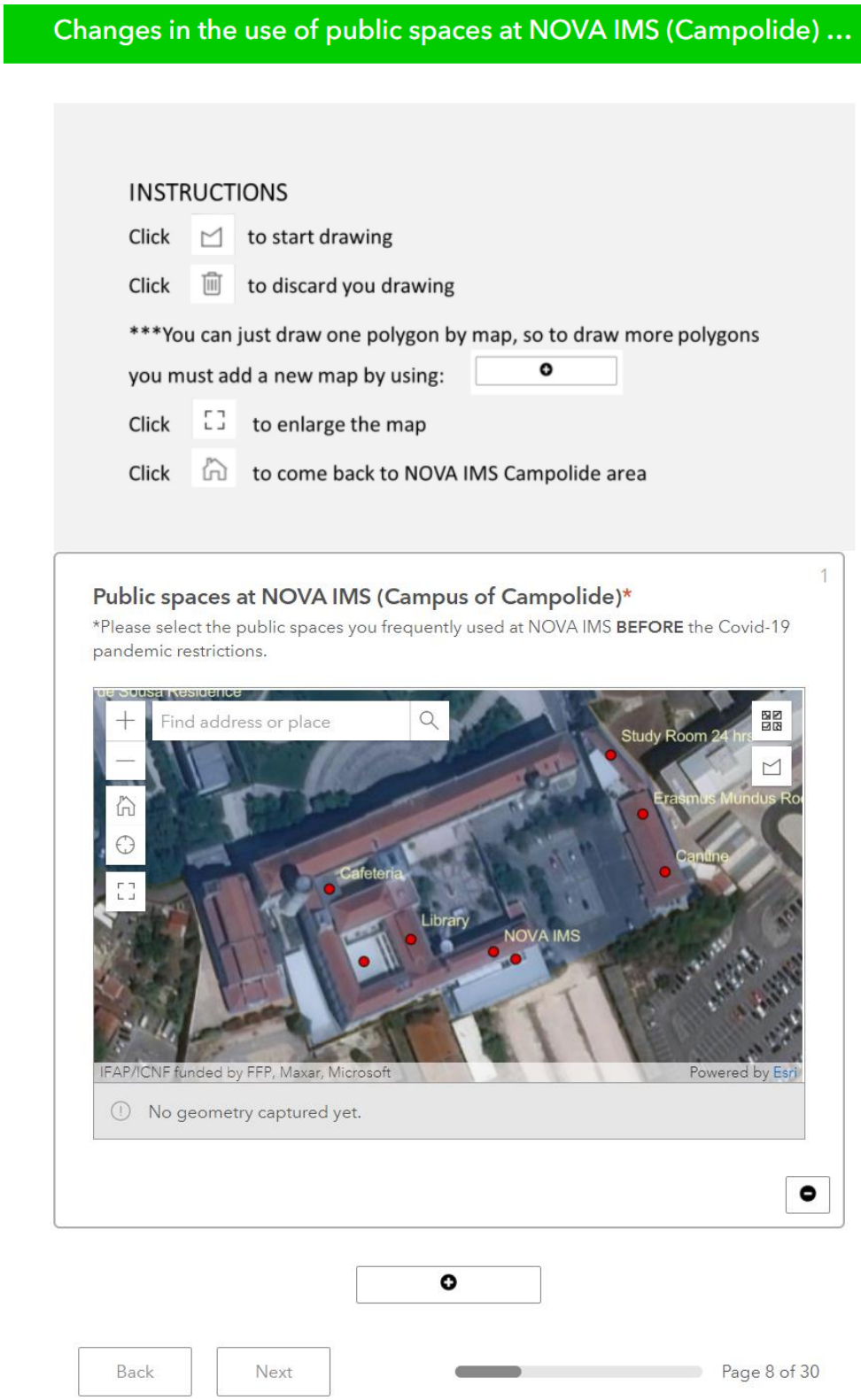

Figure 7. Instructions to draw polygons in section 2.1 Use of public spaces at Campus before COVID-19 restrictions

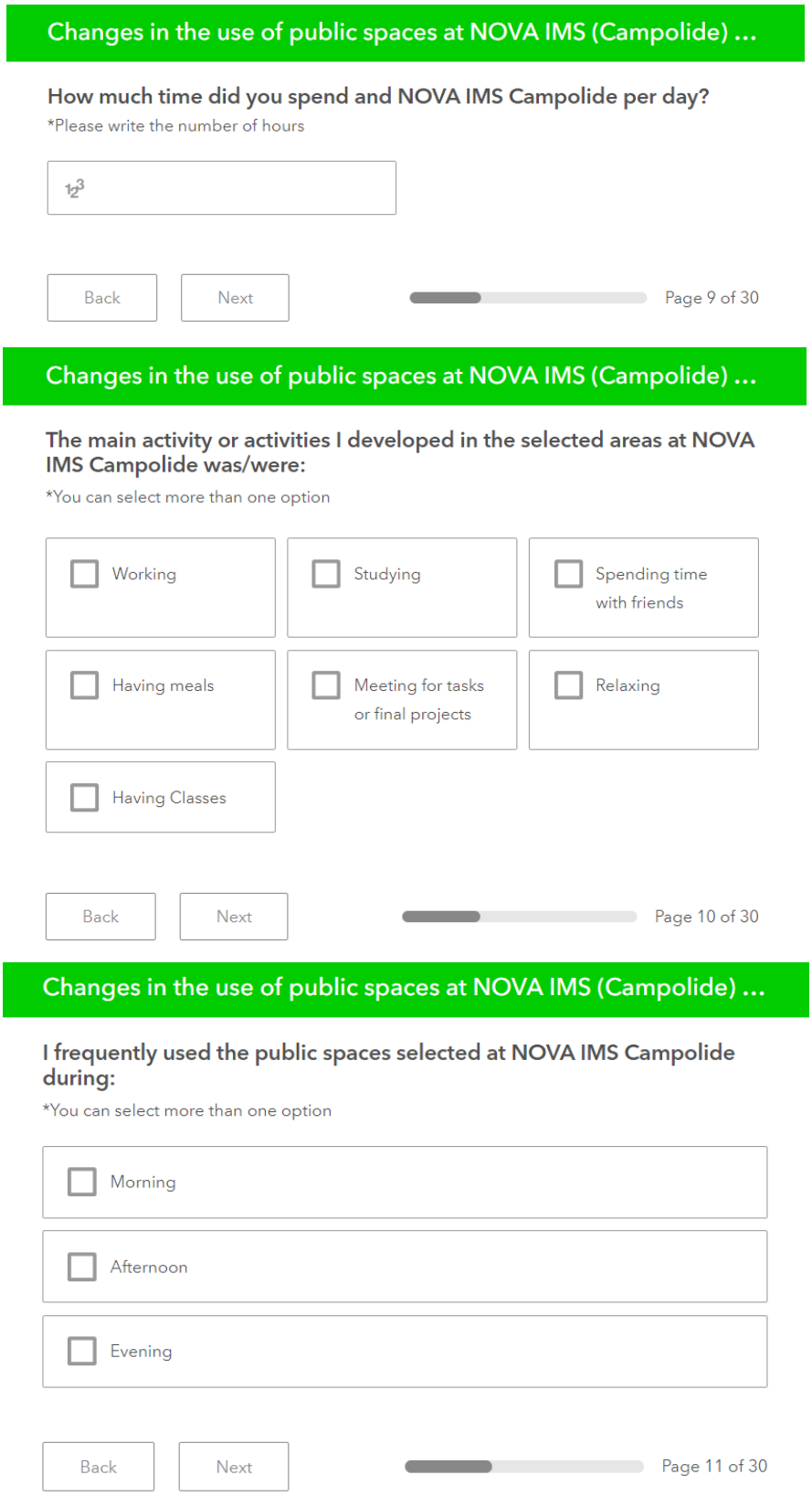

Figure 8. Questions regarding section 2.1 Use of public spaces at Campus before COVID-19 restrictions

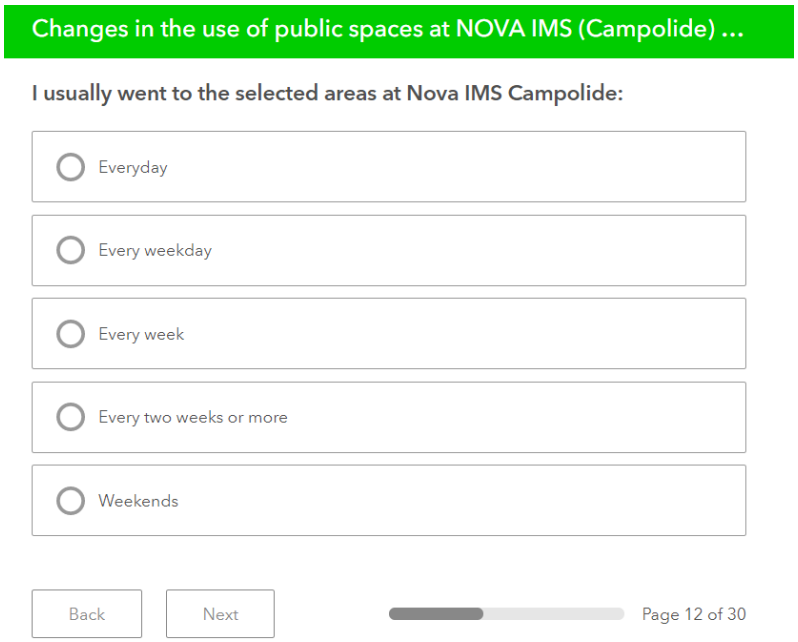

Figure 9. Questions of frequency of section 2.1 Use of public spaces at Campus before COVID-19 restrictions

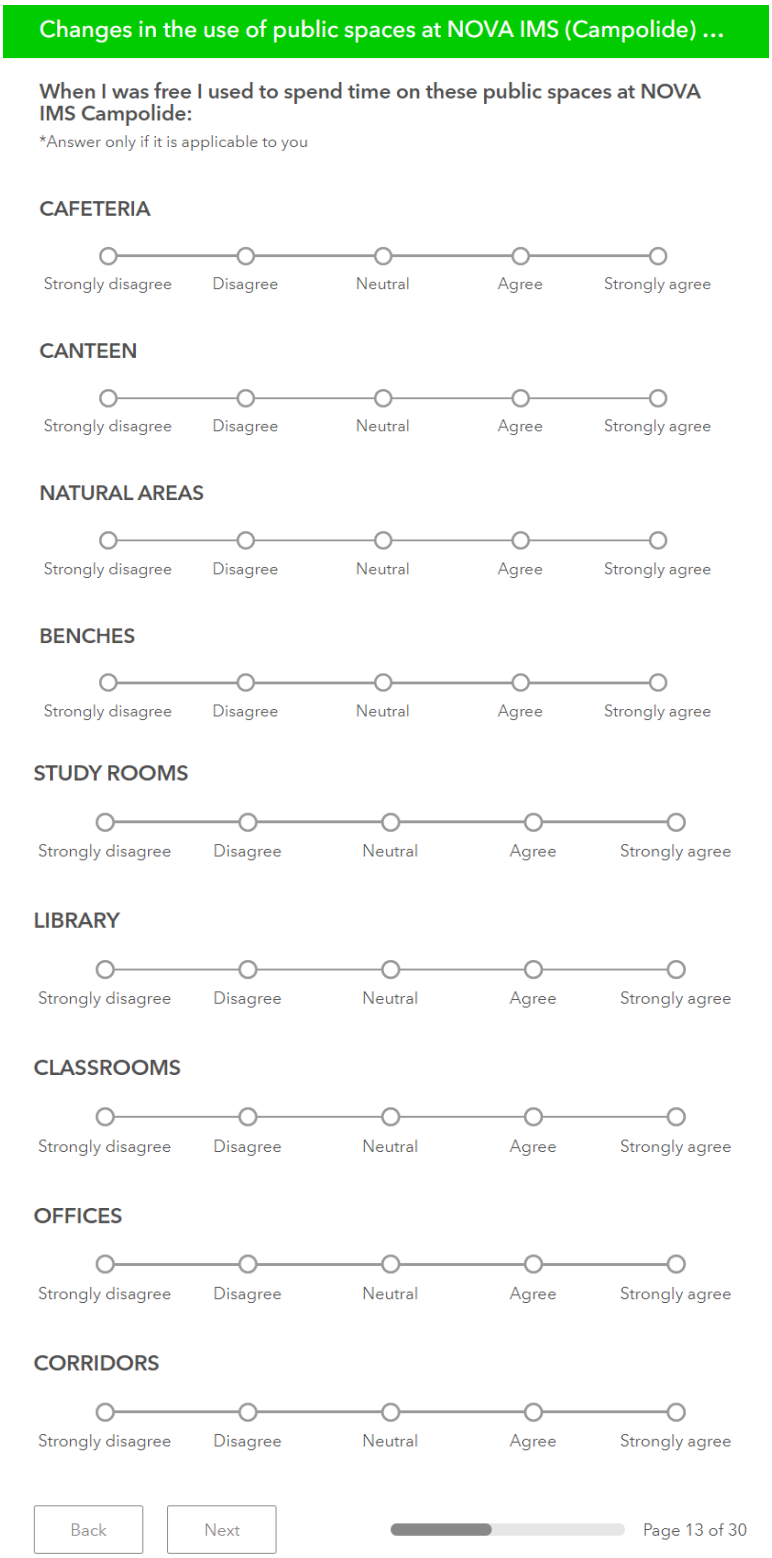

Figure 10. Perception of spending time in public spaces at Campus before COVID-19 restrictions

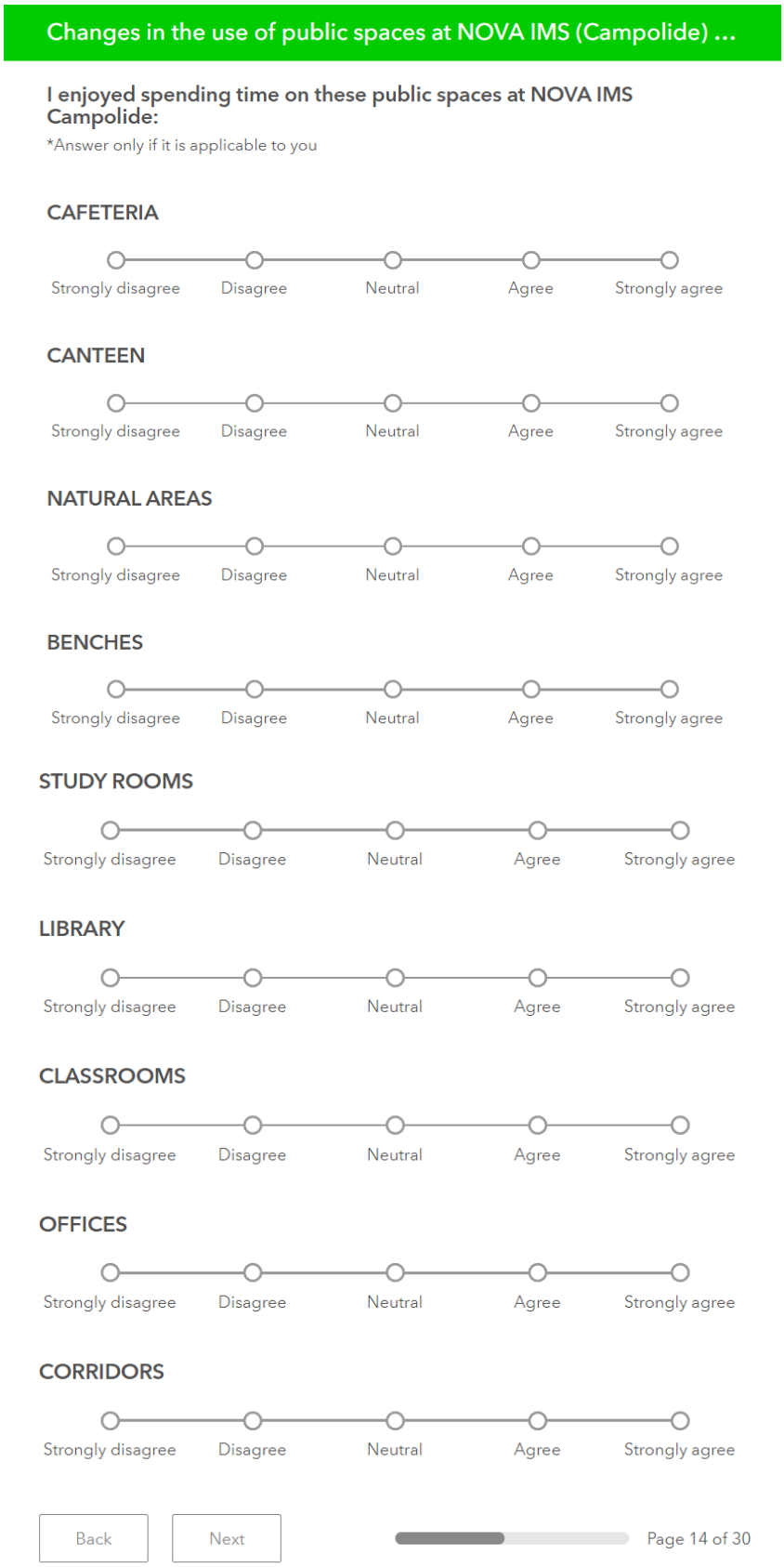

Figure 11. Perception of enjoying public spaces at Campus before COVID-19 restrictions

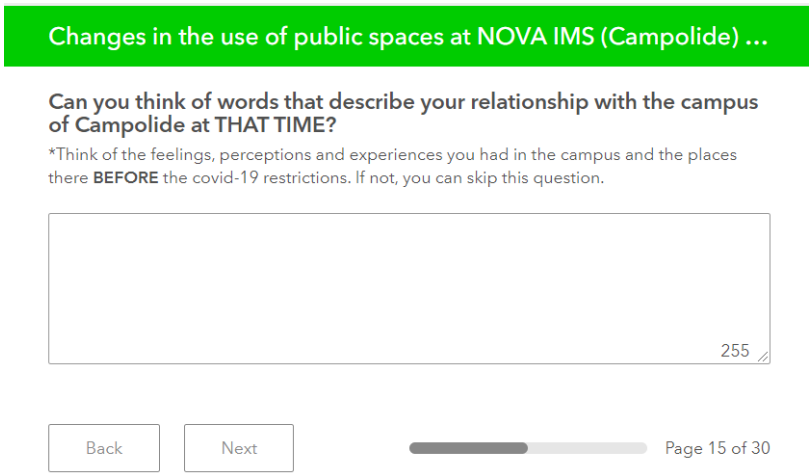

Figure 12. Words to describe relationships in public spaces at Campus before COVID-19 restrictions

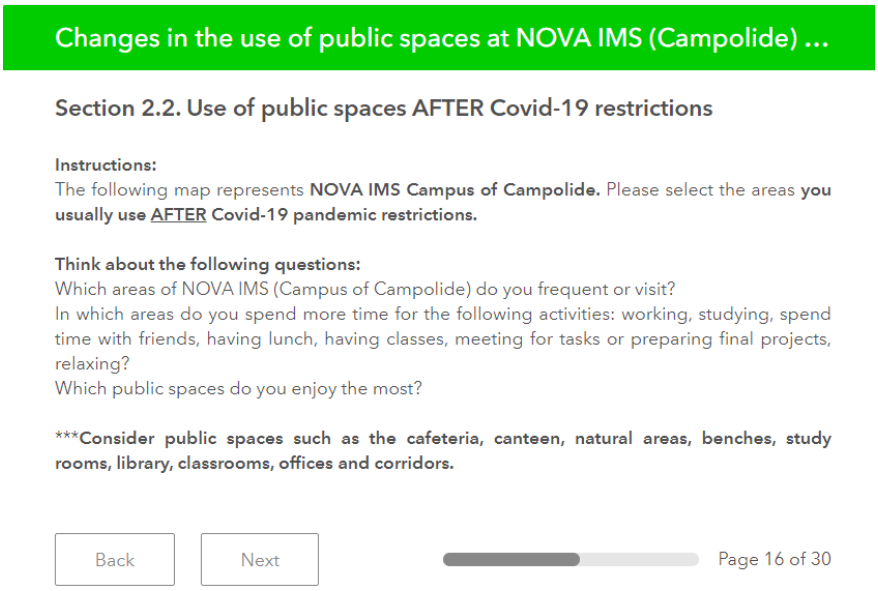

Figure 13. Instructions of section 2.2 Use of public spaces at Campus after COVID-19 restrictions

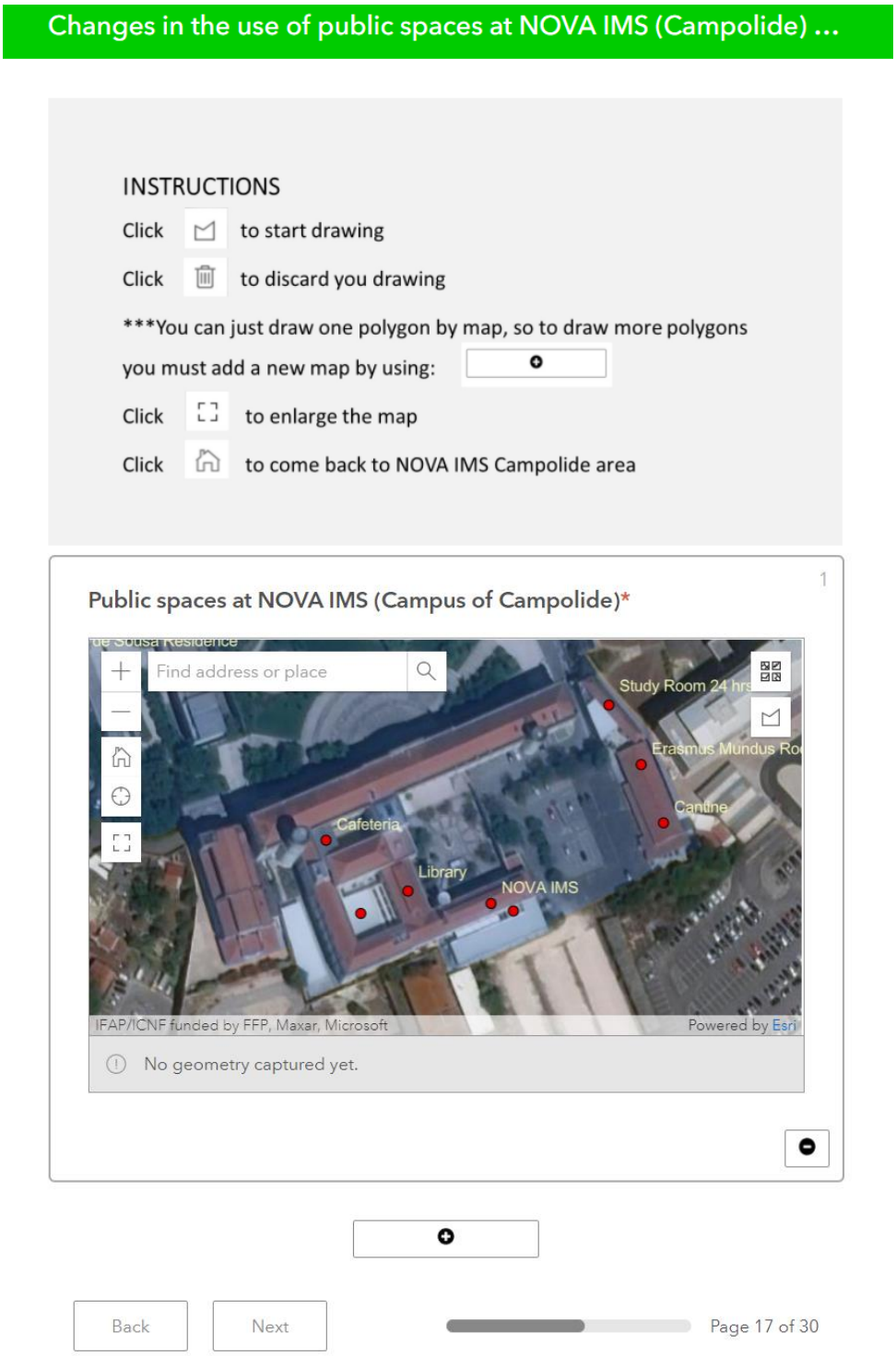

Figure 14. Instructions to draw polygons in section 2.2 Use of public spaces at Campus after COVID-19 restrictions

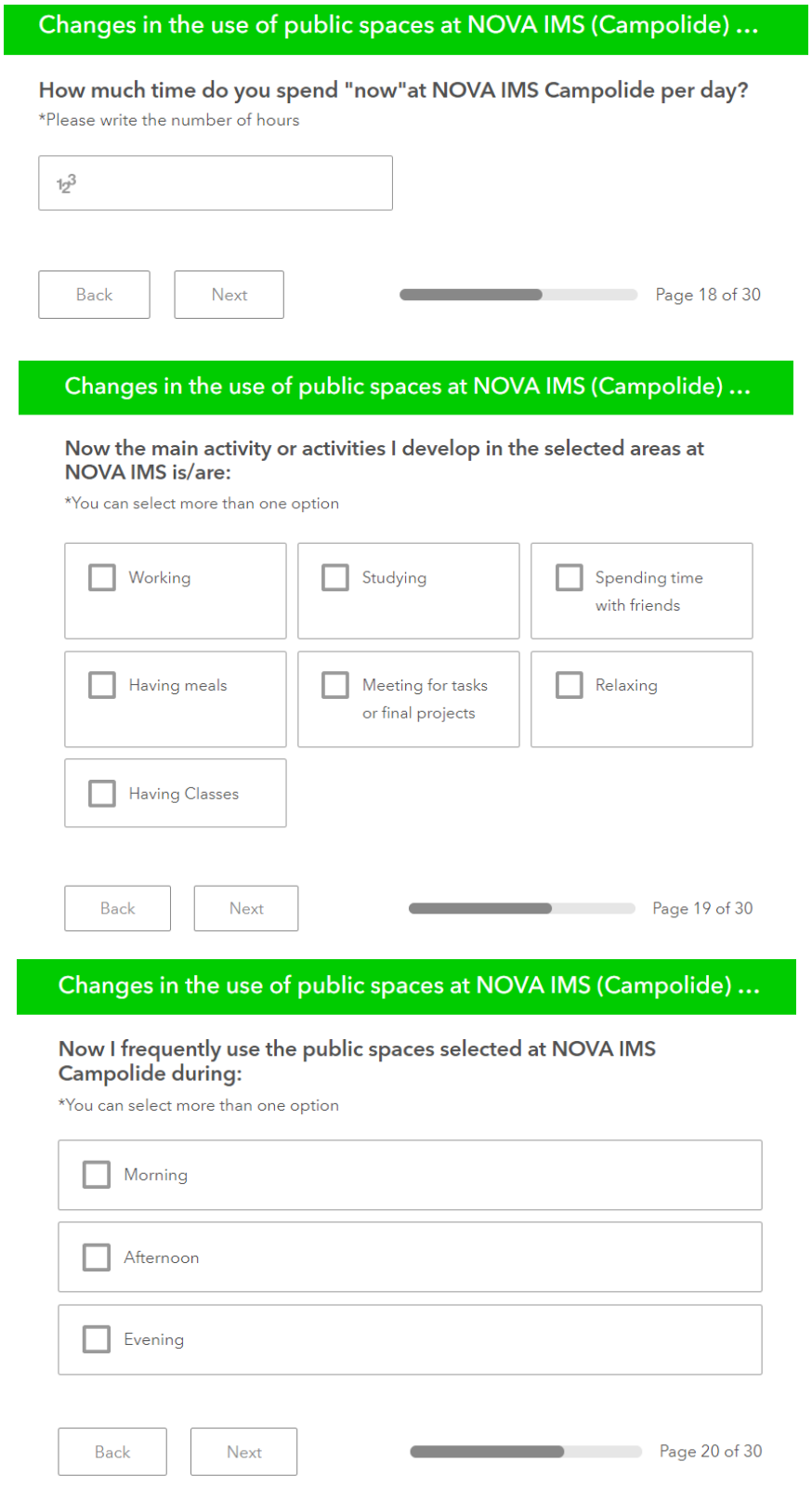

Figure 15. Questions regarding section 2.2 Use of public spaces at Campus after COVID-19 restrictions

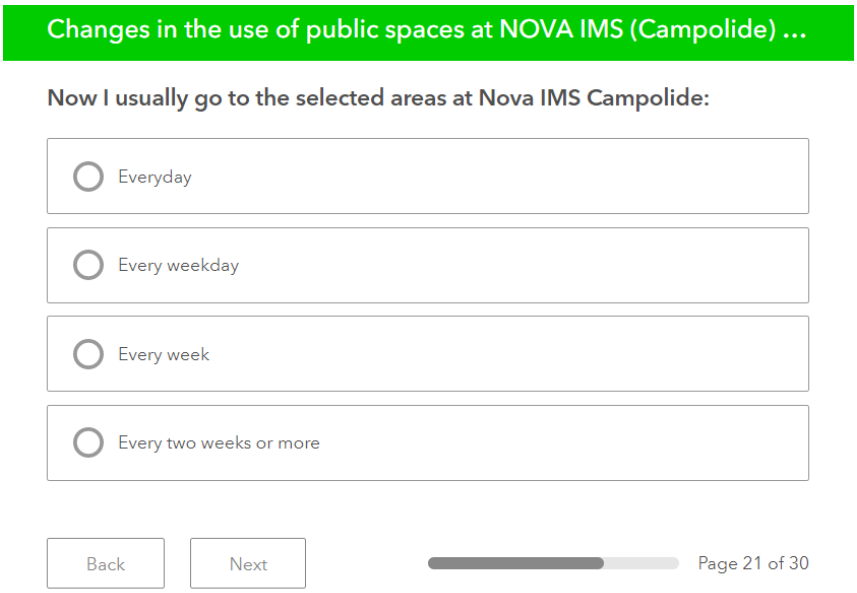

Figure 16. Questions of frequency of section 2.2 Use of public spaces at Campus after COVID-19 restrictions

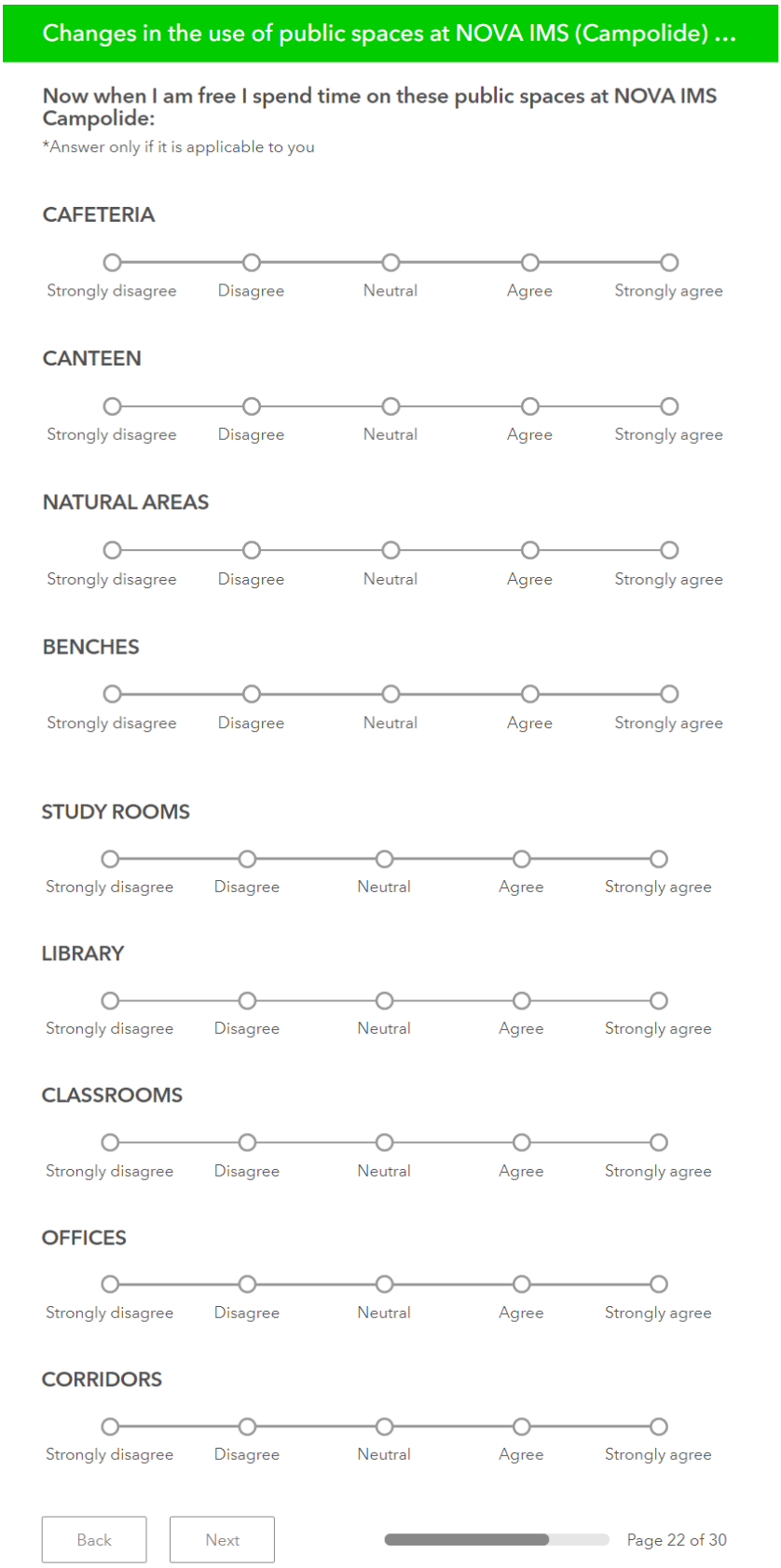

Figure 17. Perception of spending time in public spaces at Campus after COVID-19 restrictions

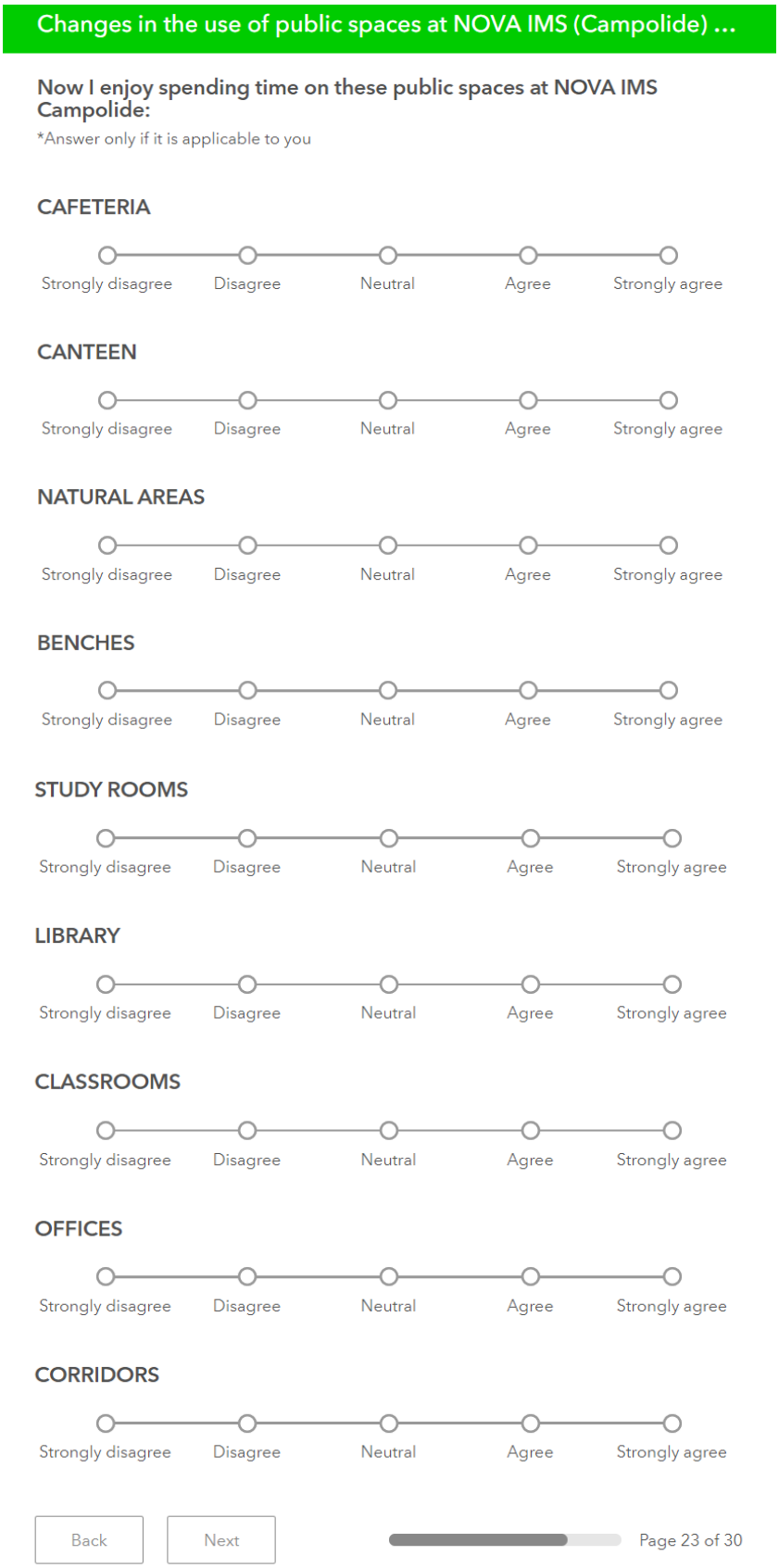

Figure 18. Perception of enjoying public spaces at Campus after COVID-19 restrictions

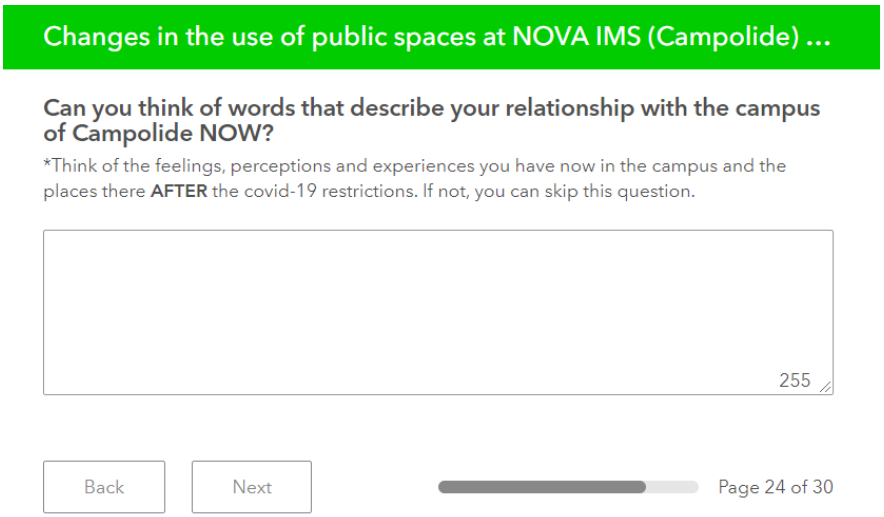

Figure 19. Words to describe relationships in public spaces at Campus after COVID-19 restrictions

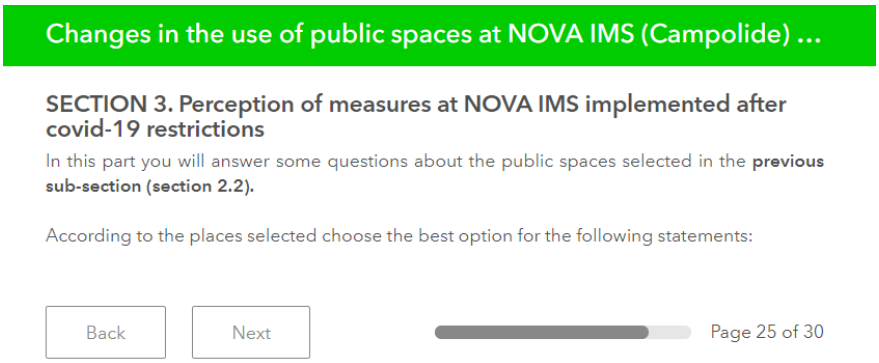

Figure 20. Presentation to section 3 Perception of measures at Campus of Campolide

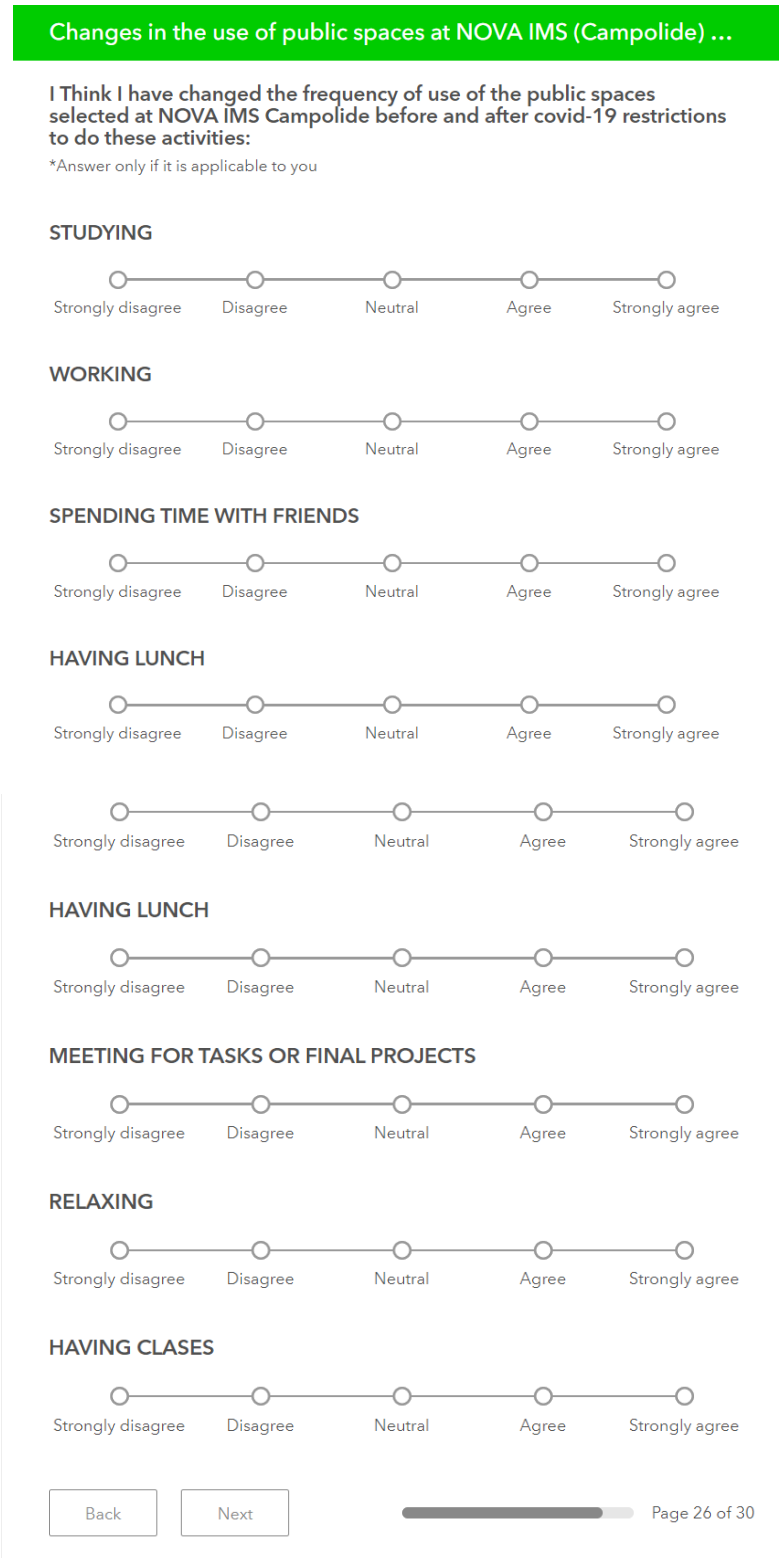

Figure 21. Perception of frequency in the use of public spaces at Campus of Campolide

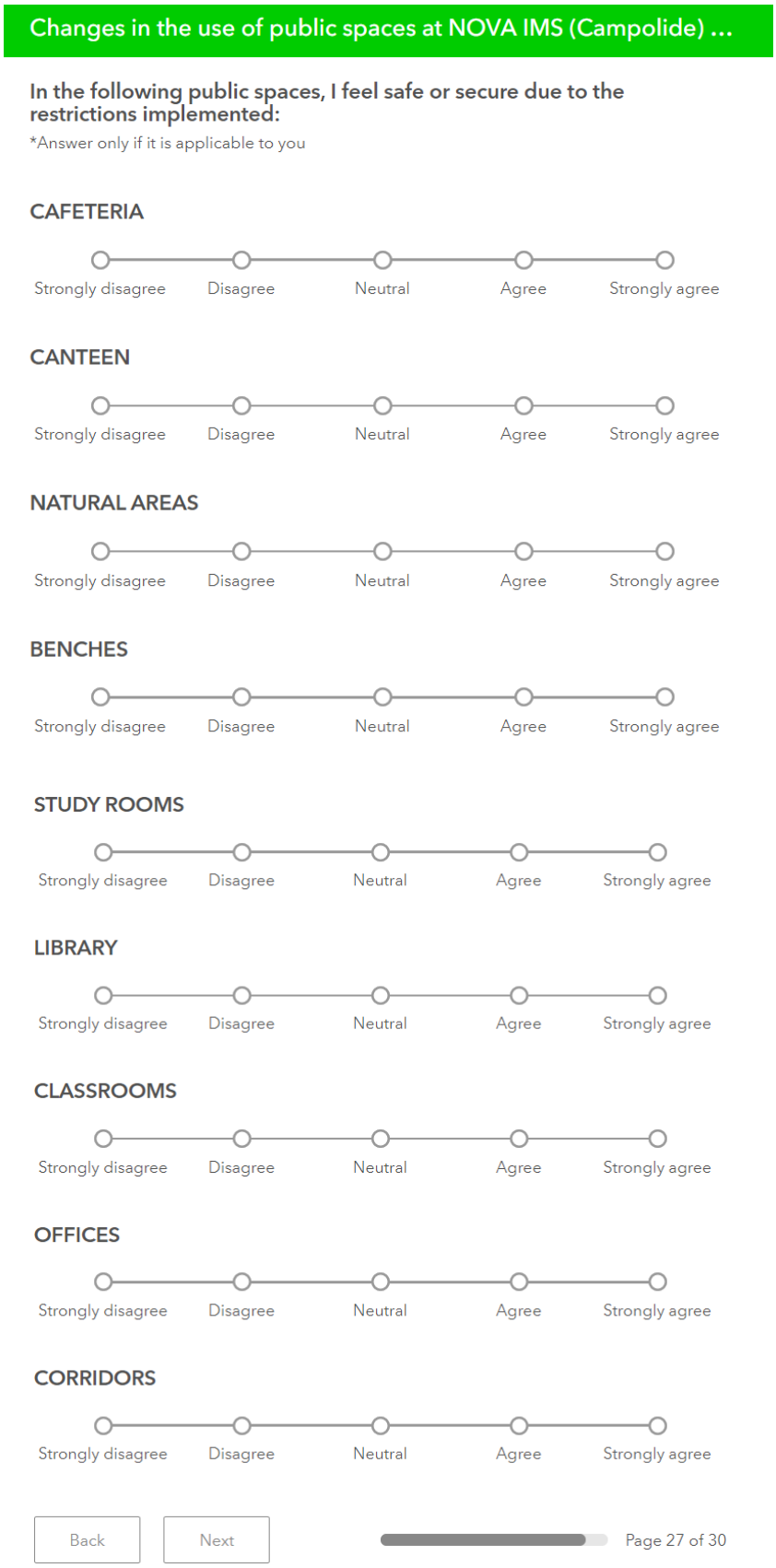

Figure 22. Perception of safeness or security in the use of public spaces at Campus of Campolide

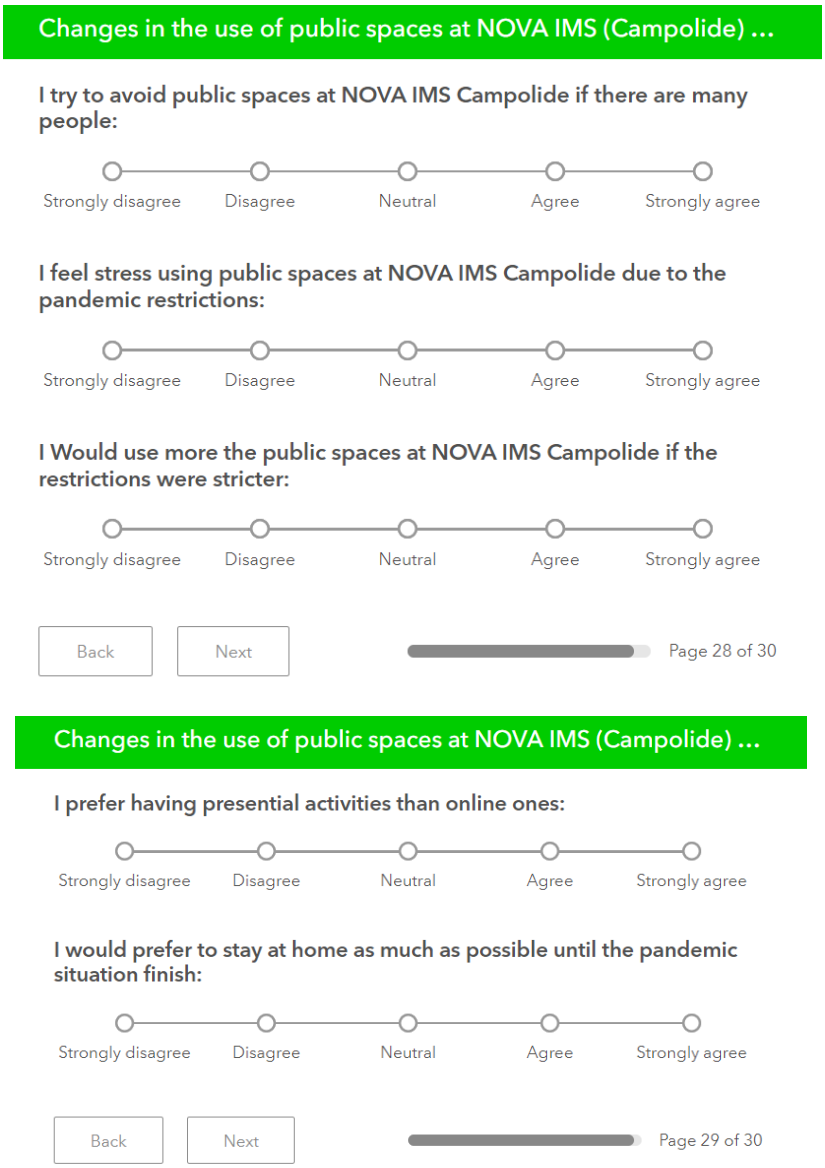

Figure 23. Perception of current situation of public spaces at Campus of Campolide due to COVID-19

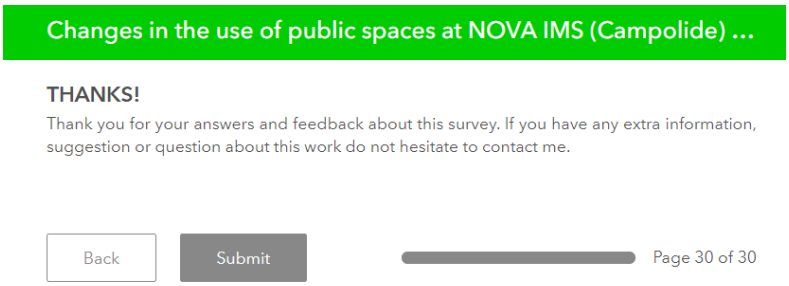

Figure 24. End of the survey

Figure 25. Centroids generated from the polygons drawn by participants

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