Extensivity: finding evidence of map interpretation skills among students and experts in the GIS field

A statistical analysis based on survey results on the ability to distinguish between extensive and intensive measures in cartographic maps.

Abstract:
The field of Geographic Information Science (GIS) has taken an important role in the scientific community as well as in the business world. In order to make GIS more accessible to researchers from other disciplines, the concepts that play a big role in the decision making processes while using GIS software and analysis must be clearly studied and defined. This research takes a look at the concept of extensivity in GIS, defined as a property of measurements of quantities with respect to a controlling quantity, such that a sum of the latter implies a sum of the former. A survey was made to test the intuitive notion of this concept, which is fairly new to GIS, among beginners and experts in the field. This study has shown that participants can distinguish between extensive and intensive measures. On top of that this study has shown that GIS experience has a significant influence on that ability to distinguish between extensive and intensive measures.

Bachelor Thesis - June 2023
Mick Raamsteeboers - 6588514
Supervisor: Eric Top MSc

Preface

Before you lies the bachelor's thesis "Extensivity: finding evidence of map interpretation skills among students and experts in the GIS field". This thesis was written as part of the bachelor's programme Human Geography and Spatial Planning at the Utrecht University. I have worked from February to June 2023 on the study and writing of this thesis.

For the longest time I have been unsure as to my plans for the future. Constantly doubting between different subjects to pursue and unsure what to choose in the end. During the very broad bachelor's programme of Human Geography and Spatial planning I got to experience a lot of interesting subjects. Two among those have sparked my interest the most, namely: Political Geography and International relations, in which I finished a minor, and GIS. Therefore I was very excited to work on a GIS subject for my bachelor's thesis. My hopes were that when I would dive deep into one of the subjects that I could not choose between, this could give me experience on which to base my decisions for the future. I can now confirm that writing this thesis has taught me valuable lessons on both personal and professional level.

I would like to thank my supervisor, Eric Top, for helping me throughout the entire process. During our many talks you have taught me much about the subject but more importantly you helped me get back on track when I felt lost more than once. With your relaxed and down to earth attitude you were able to motivate me time after time. Additionally I would like to thank all those who helped me during the data collection for this study.

Finally I want to give special thanks to my family and friends who have supported me throughout the process of writing this thesis.

I hope you find this thesis enjoyable and informative

Mick Raamsteeboers

Utrecht, June 27th, 2023

Table of contents

Introduction

Geographic Information Science (GIS) has become an indispensable tool in various research fields, revolutionising the analysis and visualisation of spatial information. As the significance of GIS continues to grow in the modern world, it becomes essential to understand how individuals comprehend some of the key concepts of the field. One such concept is extensivity, which plays a crucial role for effective analytical and cartographic practices. The aim of this thesis is to investigate the recognition of extensivity in geographical data by users with a range of experience in the GIS field.

The field of GIS has continued to grow since Kuhn's influential article about core concepts in GIS, in which he stated that "Geographic information science is emerging from its niche 'behind the systems', getting ready to contribute to transdisciplinary research" (Kuhn, 2012, p. 2267). According to Esri, the world's leading supplier in GIS software, over 350.000 organisations make use of their products. These organisations include fortune 500 companies as well as national and local governments and universities (Esri, n.d.-a). Today GIS is used in countless fields of research ranging from environment to urban planning and business and many articles are written about its importance in those fields (USC, 2021; National Geographic, n.d.).

As GIS software gains more and more use it is essential that some of the processes in GIS are automated, at the time of writing this thesis however, the software does not distinguish between extensive and intensive measures. A distinction that is important because as Scheider and Huisjes (2019) state: "the decision whether analytical and cartographic measures can be meaningfully applied depends on whether an attribute is considered intensive or extensive". They also note that for a skilled analyst it is intuitively clear that when aggregating two areas some measures can simply be summed up whereas other measures need to be weighted to arrive at a reliable estimate. However, it is not clear what this intuitive ability is based on and to what extent less skilled analysts possess this ability. Top et al. (2022) suggests that the intuitive notion of what is essentially the difference between extensivity and intensivity in measures, should be tested on empirical data.

Top et al. (2022) wrote an extensive article about the semantics of extensivity in geographical information in which they suggest a clear all encompassing definition of extensivity that can be used in various domains of measurement. This is in line with the endeavours of Kuhn to "cut across all disciplinary and technological boundaries by defining a set of core concepts of spatial information, intended to support a broader use of spatial information in science and society” (Kuhn, 2012, p 2269). By establishing and defining core concepts that are supposedly understandable for scientists across all disciplines Kuhn attempts to lift GIS to a multidisciplinary level. A clear set of core concepts is undeniably useful for interdisciplinary work.

The goals of this thesis are to make steps towards investigating whether adding the concepts of extensivity and intensivity to Kuhn’s set of core concepts would be worthwhile. This is done by conducting a quantitative study that explores the intuitive notion of the concepts of extensivity and intensivity among GIS experts, as well as beginners. With these goals in mind the main research question of this thesis is formulated:

To what extent can students and experts in the GIS field use GIS experience and cartographic knowledge to distinguish between cartographic maps based on extensive and intensive measures?

This question is divided into the following three sub-questions; first it needs to be established that it is possible for people to distinguish between maps based on extensive and intensive measures regardless of their familiarity with the concepts. This is explored through the following sub-question: *To what extent is it possible for students and experts in the GIS field to distinguish between cartographic maps based on extensive and intensive measures?*

Furthermore it is important to investigate whether GIS experience and/or cartographic knowledge influence a users ability to distinguish between extensive and intensive measures on maps which is done through the following two sub-questions: *To what extent is the ability to distinguish between cartographic maps based on extensive and intensive measures influenced by GIS experience?* and *To what extent is the ability to distinguish between cartographic maps based on extensive and intensive measures influenced by cartographic knowledge?* This thesis will explore these three sub-questions and the main question by using a survey based on previous work (van Ark, 2022).

Theoretical framework

This chapter provides the theoretical background that is relevant and on which this research and thesis is based. First and foremost, extensivity and its role in geographical data is discussed, then cartographic rules that are tied to the concept of extensivity such as proportional symbol maps and choropleth maps are considered. Following that, the theory around core concepts of spatial information is discussed. Next, some theories around conducting a survey with experts and beginners is considered. Attention is given to theories like the memory effect and the Dunning Kruger effect. Finally, some relevant literature in which similar research and surveys have been conducted is brought to attention in order to learn about the choices made in these studies.

Extensivity in geographical data

The concepts of extensivity and intensivity find their origins in physics and chemistry. The latter field has a conveniently substantial compendium in which all terminology of quantities, symbols and units in chemistry is compiled, namely the *Compendium of Chemical Terminology*. In this compendium, published by the International Union of Pure and Applied Chemistry (IUPAC, 2019), the following definitions for extensive and intensive quantities are given:

- *Extensive quantity:* ‘Physical quantity whose magnitude is additive for subsystems’

- *Intensive quantity:* ‘Physical quantity whose magnitude is independent of the extent of the system’

In physics, perhaps the earliest mention of the terminology of extensive measures and intensive measures is made by Hegel (1812) who notes that extensive and continuous should be distinguished from each other and the direct opposite of extensive is intensive and not discreet, which is the opposite of continuous. Hegel explains that extensive and intensive magnitudes are characteristics or aspects of the very limit of quantity itself. They are properties that keep to the boundaries and endpoints of a quantitative measure. Continuous and discrete magnitudes however, represent ways of measuring quantity itself and are independent of the boundaries of such quantity (Hegel, 1812). Important to take from this is the distinction between extensivity and intensivity on the one hand and continuous and discrete on the other.

More than a century later Tolman (1917), a mathematical physicist and physical chemist, also discusses extensive and intensive measures; he introduces the spatial component with spatial extensiveness and spatial intensiveness. Tolman states that the magnitude of extensive characteristics, expressed in numbers that can be summed, depends on the size of a system, for example mass and volume; however, the magnitude of intensive characteristics, indicated by numbers that can not be summed, is independent of a system's size, for example temperature and pressure (Tolman, 1917).

The introduction of the concepts in geosciences appears much later which could be attributed to the fact that geosciences in itself is a relatively young field. The first mention, according to Scheider and Huisjes, is in 1980 by Goodchild and Lam in a paper discussing the properties of a technique of areal interpolation based on the use of areas of intersection as weights (Scheider & Huisjes, 2019; Goodchild & Lam, 1980). Perhaps more directly useful for this thesis and more contemporary is the discussion by Jaeger in 2000 who examines the use of extensive and intensive properties in landscape division. He defines the two concepts as the following (Jaeger, 2000):

> "Being intensive means remaining constant when the analysed region is being enlarged but keeping its structure. This property is a precondition for the interpretation of an index as quantifying an intrinsic feature. If the index increases by the same factor the region is multiplied by, it is called extensive."

These are only some earlier mentions of the concepts in geosciences. Especially in the past few years the concepts have become more prevalent. Scheider and Huisjes (2019), who were briefly mentioned in the introduction chapter, discuss the problematic nature of the concepts as they are currently not easily distinguished by GIS software. Problematic because the meaningful application of analytical and cartographic measures relies heavily on the classification of attributes as either intensive or extensive. Currently these concepts are often some of the underlying phenomena that lead to the Modifiable Area Unit Problem (MAUP), a notorious issue in spatial statistical analysis, when understood as the problem of reconstructing attributes for the base units (Scheider & Huisjes, 2019).

The most recent article discussing extensivity and intensivity in GIS is by Top et al. (2022). In this article the authors hold a comprehensive discussion on the semantics of the concept of extensivity. The authors recognize that there are multiple dimensions of extensivity, other than just space and they subsequently argue that extensivity needs to be defined as a relation between domains of measurement. Thus extensivity is defined as:

“a property of measurements of quantities with respect to a controlling quantity, such that a sum of the latter implies a sum of the former” (Top et al., 2022).

For intensivity, being the opposite of extensivity, a sum of the controlling quantity therefore does not imply a sum of the former quantities. This definition is the one that will be used for this research as it is the most precise definition for use in the GIS context.

Cartographic rules, choropleth maps and proportional symbols

This subchapter explores the cartographic rules tied to mapping extensive and intensive measures. Although it is sometimes not explicitly mentioned as being tied to the concepts of extensivity and intensivity, because these concepts are relatively unknown and new in GIS, there are actually clear cartographic principles regarding the correct way to map certain attributes and measures.

Mapping certain attributes and measures is done through visual variables. The first time the concept of visual variables was systematically identified was in 1967 by Bertin. In his book Bertin pointed out a set of basic variables such as size, shape, colour and orientation and explained how and when to use them (Bertin, 1967). This set has since been widely used and expanded upon but forms some of the basis of cartographic rules.

When applying cartographic rules it is important to keep in mind that maps are a representation of reality and can therefore never perfectly represent reality. In order to create an effective map the mapmaker has some decisions to make about how to effectively portray the goals of the map. As Monmonier (2014) writes: “To portray meaningful relationships for a complex, three dimensional world on a flat sheet of paper or screen, a map must distort reality.” (Monmonier, 2014, p 1.) This means that for an effective map some details must be left out and others might be emphasised or made bigger than they actually are.

That is not to say there are no rules that mapmakers should adhere to. Selecting and implementing appropriate techniques for symbolising spatial data is sometimes referred to as the ‘cartographic process’. This process is important to create correct and meaningful maps all the while avoiding confusion or misinterpretation (Slocum et al., 2022). Part of this process is selecting the right type of map to display your data.

Two types of maps, that are relevant for this study, are choropleth maps and proportional symbol maps. An example of both maps is shown in figure 1, the choropleth map is a statistical thematic map that uses colour or shades of colour to signify data intensity within spatial enumeration units using ordinal classes (Heywood et al., 2011). The second map type, the proportional symbol map, is a map with symbols, usually circles, that represent quantitative values as a series of unclassed symbols sized according to each specific value (Esri, n.d.-b).

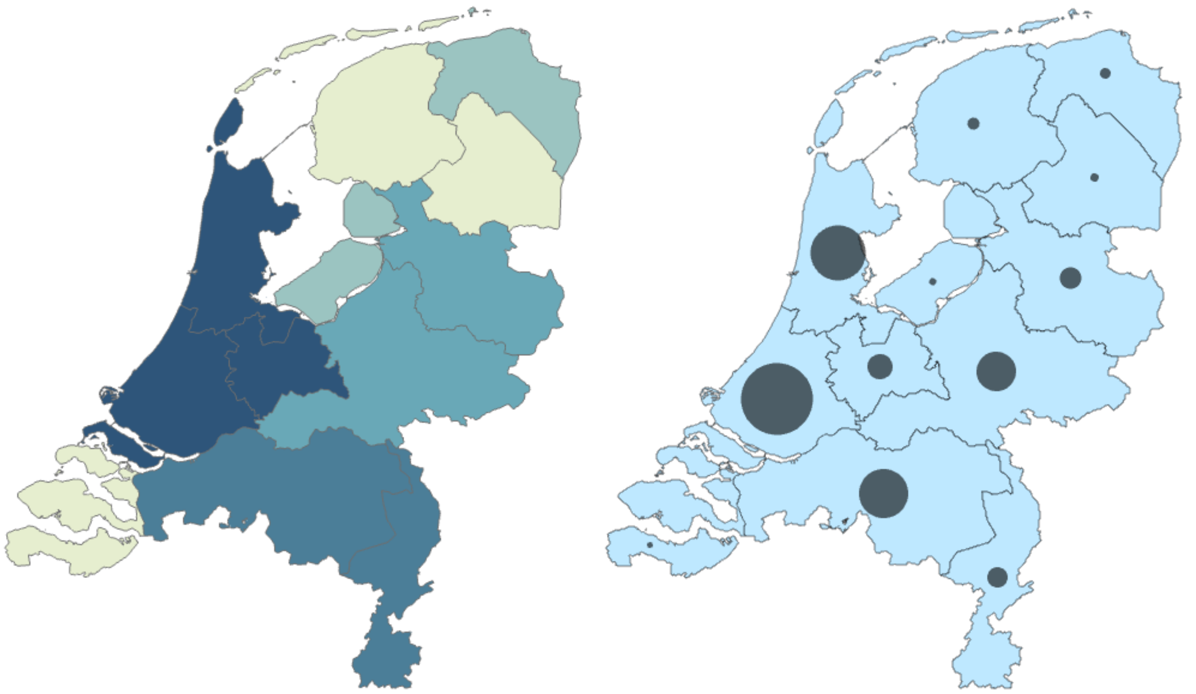

Figure 1. *Choropleth map of population density of the Netherlands per province (left) and a proportional symbol map of total population of the Netherlands per province (right). Population data gathered from CBS StatLine (n.d.).*

As Kraak and Ormeling (2021) put it: “Selection of either absolute or relative representation also implies the selection of a specific cartographic method that is for proportional symbol maps or choropleth maps, respectively.” This distinction between absolute and relative can be applied to the concepts of extensiveness and intensiveness. As most absolute data is extensive and all relative or normalised data is intensive, the appropriate maps are indeed choropleth and proportional symbol maps respectively. Scheider & Huisjes confirm this notion saying choropleth maps are only appropriate for displaying intensive data. They go on to explain that when mapping extensive properties on a choropleth map, the large polygons would automatically stand out thus giving the reader an incorrect impression of the phenomenon under study, making it seem as though the large areas are more important than they really are (Scheider & Huisjes, 2019).

Core concepts of Spatial Information

As was briefly touched upon in the introduction, the core concepts of spatial information introduced by Kuhn (2012) are meant to create a bridge between different scientific disciplines. Kuhn argues that many of the big contemporary challenges of humanity are to be tackled by transdisciplinary approaches and believes spatial information and spatial technologies can contribute greatly. However, GIS lacks a clear and simple list of concepts that would allow researchers from other disciplines to easily understand how to apply GIS in their own studies.

Janelle and Goodchild (2011) first proposed a list of 'foundational concepts in spatial thinking', which was mostly targeted at the social sciences and contrary to Kuhn's list which is built for spatial information, Janelle and Goodchild created a list for spatial thinking. Kuhn's (2012) core concepts are meant to cut across all disciplinary and technical boundaries and are meant for a much broader audience. In the introduction of this thesis it was proposed that the concepts of extensivity and intensivity, in some form, could be a valuable addition to the list presented by Kuhn.

Kuhn (2012) suggests ten core concepts, spatial concepts that allow researchers to think about space and information concepts to provide context on spatial information. The former concepts describe content while the latter present representation of said content. Of the ten concepts proposed by Kuhn six are spatial concepts namely: *Location, Neighbourhood, Field, Object, Network* and *Event*. The four remaining concepts are information concepts: *Granularity, Accuracy, Meaning* and *Value*.

Since the introduction of the core concepts of spatial information substantial research has been done to analyse and describe them in more detail, as well as to test the applicability of the concepts (Vahedi, Kuhn & Ballatore, 2016; Kruiger et al., 2020; Scheider et al., 2020; Nyamsuren et al., 2022). Many of these studies provide evidence that the implementation of the core concepts could indeed make using GIS processes faster, more convenient, more precise and more easily understood.

The Memory effect and the Dunning Kruger effect

This study uses a survey to gather data, in the survey the respondent is asked to answer the same question sixteen times for different maps. The repeated exposure to the same survey question could influence respondent's interpretations and responses. As respondents get more familiar with the question, get repeated exposure to the same task and learn from previous iterations, their answers to the later question could be influenced. Although this specific effect has not been discussed much in academic literature, a similar theory named the memory effect has been touched upon in depth by Schwarz, Revilla and Weber (2020) who investigate how well respondents remember their previous answers to similar questions. Their article shows that, even in longer surveys of 20-30 minutes, most respondents were able to remember their answers to previous similar questions.

Because the survey will be spread among GIS users with a range of expertise, another theory that could be relevant is the Dunning-Kruger effect. Named after the creators of the theory who first introduced it in 1999. Kruger and Dunning explore the phenomenon of people with low ability in a particular domain having inflated self-assessments of their competence (Kruger & Dunning, 1999). Dunning, Johnsen, Ehrlinger & Kruger (2003) expand upon their previous work and elaborate that poor performers are doubly cursed. First their lack of skill means that they are unable to produce correct responses, secondly poor performers also lack the necessary expertise to surmise the fact that their responses are incorrect. However, it is not only unskilled individuals who poorly estimate their own skill, highly skilled people also suffer a burden. In their research the authors found that these top performers tend to underestimate their own rank relative to people with whom they compare themselves. The source of this underestimation is not that these skilled individuals are unable to correctly estimate their own skill, rather they tend to overestimate the skill of others (Dunning, Johnsen, Ehrlinger & Kruger, 2003).

Finding empirical evidence of concept recognition

This research attempts to find evidence of the ability to recognize certain concepts when used in cartographic maps, extensivity and intensivity. A similar study has been conducted by Nyamsuren et al. (2022) on the topic of Kuhn's core concepts. Their article articulates a similar research goal, namely to find empirical evidence of concept recognition for the core concepts defined by Kuhn. In their research they focus specifically on two concepts, object and field. Since the study of Nyamsuren et al. is so similar to that of this thesis, many lessons can be learned from their research.

Nyamsuren et al. (2022) used a survey based on the contrast model in which the respondents had to pick the odd one out between three maps where two maps represent one core concept while the other map represents a different core concept . This proved to be an efficient way of surveying concept recognition and this method can be replicated with extensive and intensive measures in this study.

In their discussion of the results Nyamsuren et al. theorise about some strategies used by the participants. One of these strategies is that respondents would simply pick the map that looked visually the most different from the other two maps which led to a correct answer on some questions but more often to the wrong answer. This theory is backed up by an effect that is based in neuroscience and well discussed by Wolfe and Horrowitz (2004). In their article they mention that some attributes are certain to guide visual attention. These are attributes such as colour, movement, orientation and size. On top of that Wolfe and Horrowitz name shape in most cases to be probable to guide visual attention. Colour, size and shape are all important attributes in cartography as discussed in the subchapter on cartographic rules and the strategy theorised by Nyamsuren et al. could very well apply to this study as well.

A second strategy that respondents could have used is theorised by Nyamsuren at al. as to compare the maps based on the attribute descriptions. It is mentioned that this is a more advanced strategy that would require more knowledge and it seems to be only effectively applied by the skilled cohort (Nyamsuren et al., 2022). Although this research does not survey any experts, the previous study by van Ark did and it could be meaningful to analyse whether those experts used a similar strategy.

Methodology

In this chapter the proposed methodology will be discussed. As mentioned in the introduction a survey will be held among GIS users with varying degrees of expertise. The survey used for this research builds forth on work by van Ark (2022). By using a very similar survey the results of both studies can be combined to perform a more meaningful analysis and comparison between the subclasses. The aim of this is to create a larger sample with a more diverse range of GIS experience and cartographic knowledge, which will allow for a more meaningful comparison between groups like beginner GIS users and experts in the field. This chapter will discuss in more detail the reasoning behind conducting this research as a survey, the structure of the survey as well as the research subjects. The chapter will then go into detail about the decisions made during the process of selecting respondents and research methods.

Survey

The central question in this research: *To what extent can students and experts in the GIS field use GIS experience and cartographic knowledge to distinguish between cartographic maps based on extensive and intensive measures?* is best answered using quantitative measures. The question aims to find how well a specific group of GIS users can use their experience and knowledge to successfully distinguish between maps based on different measures. A survey perfectly fits this aim as it can test the respondents ability to distinguish between maps by presenting them a set of questions based on such maps and measuring their accuracy in finding the correct answers. While also asking the respondents questions about their experience and knowledge. Subsequently the results of the survey can be analysed using statistical tests to investigate whether there are significant correlations, trends and differences among groups.

For this research an online survey has been chosen as a research method as to be able to reach many respondents quickly. The survey uses the same questions and mostly the same structure as the one used by van Ark (2022). It consists of two major sections with multiple choice questions which measure the respondents accuracy in distinguishing between maps based on extensive and intensive measures. Afterwards the respondents are asked to self-report their experience with GIS and their knowledge of cartographic rules surrounding choropleth maps and proportional symbol maps.

The two major sections of the survey consist of maps that are built using data from the Dutch statistical office '*Centraal Bureau voor de Statistiek'* (CBS). From this office a dataset named *'Kerncijfers Wijken en Buurten'* (CBS, 2021) was used. This dataset contains comprehensive data about all municipalities and neighbourhoods in the Netherlands, with plenty of extensive and intensive measures from which simple maps were created for the survey. Figure 2 shows examples of one extensive measure and one intensive measure mapped on the municipalities of the Netherlands in the form of a choropleth map. The map on the left shows an extensive measure, the number of men per municipality. When combining the municipalities to create provinces the number of men for each municipality in said province can be summed to reach the number of men in each province. The map on the right shows an intensive measure, the average distance to the closest hospital for inhabitants per municipality. When applying the same aggregation of municipalities into provinces, the average distances of each municipality can not be simply summed but instead a weighted mean has to be calculated. A full overview of the extensive and intensive measures used in this study can be found in appendix 1.

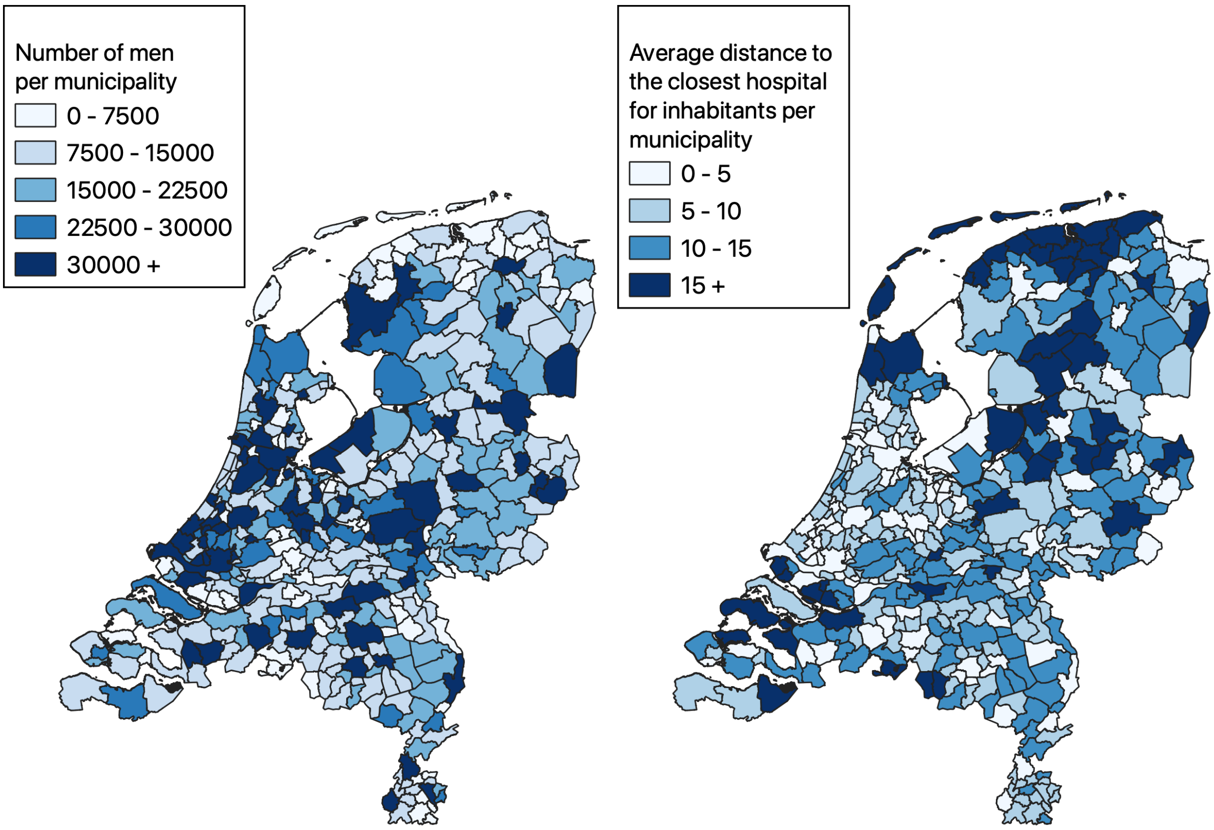

Figure 2. *Choropleth maps showing an extensive measure, number of men per municipality (left), and an intensive measure, average distance to the closest hospital for inhabitants per municipality (right). These maps are examples of the maps used in the first section of the survey.*

When visualising the measures, thought was given to creating maps that were simple and explicit in order to make them easy to interpret for respondents with diverse backgrounds and differing degrees of GIS experience and cartographic knowledge. All of the maps use the same geographical scale and a simple legend as well as having uniformity in colour and size. The maps depict only the data from the CBS dataset for municipalities and show no other topographical features.

In order to get as many respondents as possible the survey was kept relatively short, qualtrics recommends a maximum of nine minutes as their data shows that on mobile phones surveys longer than nine minutes show a substantial increase in respondents not finishing the survey (Qualtrics, n.d.). Van Ark (2022) wrote that many of his respondents did not finish the survey and he attributed this partially to the survey length, which is in line with the data from qualtrics. Hence it was decided to divide the first section of the survey into four overlapping versions of eight questions each instead of showing the respondents the original sixteen questions. Table 1 shows a schematic rendition of this division.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Version 1	■	■	■	■	■	■	■	■								
Version 2									■	■	■	■	■	■	■	■
Version 3					■	■	■	■	■	■	■	■				
Version 4	■	■	■	■									■	■	■	■

Table 1. *Schematic rendition of the division of questions in section one of the survey between four different versions.*

By dividing the survey in such a way all questions are just as common and by creating overlap between the versions a randomisation of the questions is simulated, this reduces the chance that any version is significantly easier or harder than any other version and thereby unintentionally creating a new variable. On top of creating four different versions, the questions in each version are also randomised. By randomising the questions and creating overlap between versions, the aim is to minimise the influence of the memory effect and to ensure that the versions are balanced and comparable. To be thorough a test will be done in the analysis to see if there is still a significant difference between the versions.

The survey begins with a short introduction in which the respondents get some information about the length of the survey and contact information in case they run into trouble. The goals of the survey were kept vague so that respondents would not be able to do any research on the subject. The intent was to see how well the respondents do intuitively. Therefore the respondents were only told that the survey was part of a bachelor’s thesis and that the results would only be shared with the supervisor and otherwise be kept completely anonymous. In the introduction it is also explained that a reward of €5 is available for those participants that have produced valid and complete results. The participant is then asked to give informed consent to participating in the survey.

Section one starts with an explainer in which the respondents are told they will get to see sets of three maps and it is their task to pick the map that behaves differently from the other two when aggregating the data from Dutch municipalities to provinces. An example map to visualise the aggregation operation, shown in figure 3, was also provided to the respondents. The respondents are explicitly not told that they are looking at maps depicting extensive and intensive measures as to once again keep them in the dark about the goals of the research. A meaningful aggregation operation in GIS would however differ for extensive measures and intensive measures, thus the question in section one measures the respondents understanding of the extensive or intensive property of the measures.

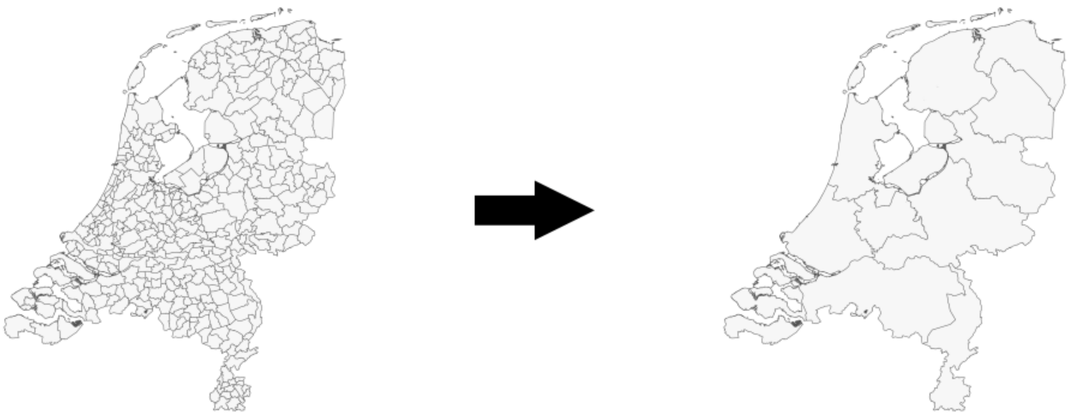

Figure 3. *Example map shown to the respondents before section one of the survey that visualises the aggregation operation. For each question in section one the respondent has to imagine this operation.*

There are sixteen questions in section one, each of the questions showing a set of three maps, where one of the maps is the odd one out. Either two maps with extensive measures and one map with an intensive measure or two maps with intensive measures and one map with an extensive measure. An example question that respondents can encounter in section one is shown in figure 4. Each set of maps was carefully considered to avoid having sets that would show two maps about one subject, such as cars, and one about another, such as housing, for example.

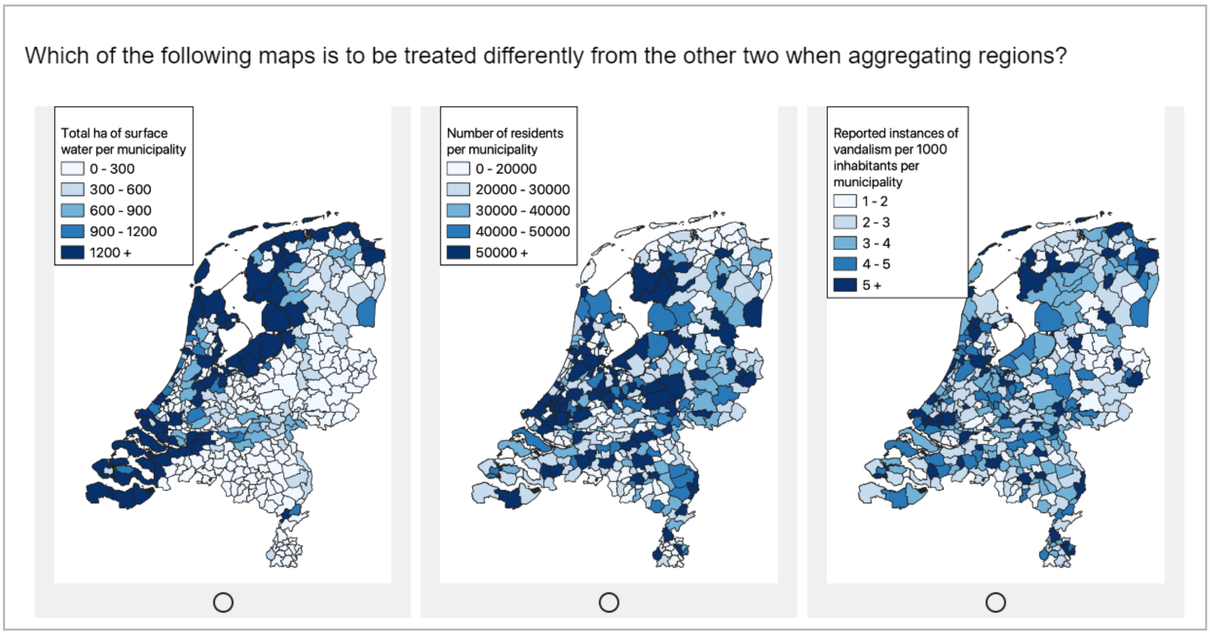

Figure 4. *Example question of section one with 3 maps. The right-most map visualises an intensive measure, normalised reported instances of vandalism, while the other two maps show extensive measures, total amount of surface water in ha. and the number of residents.*

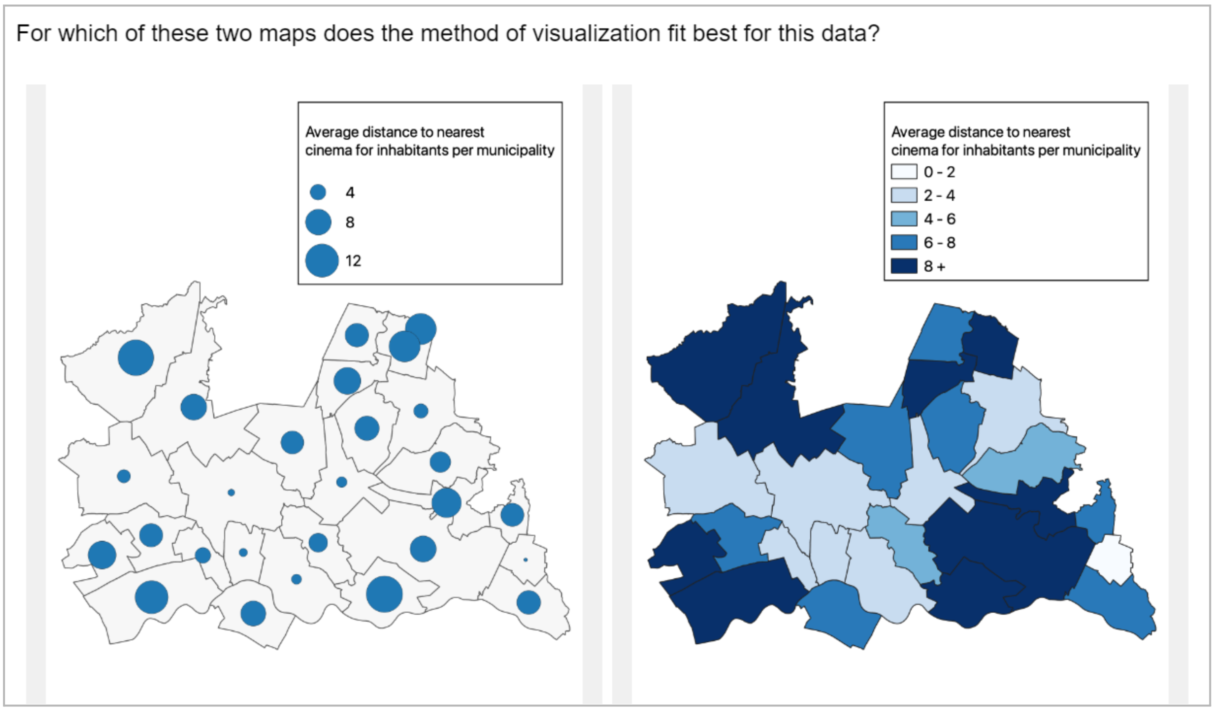

Figure 5. *Example question of section two with 2 maps depicting the same measure. One proportional symbol map on the left and one choropleth map on the right.*

In the second section of the survey, consisting of five questions, the respondents are asked to pick from a set of two maps, both depicting the same data but one as a choropleth map and the other as a proportional symbol map, an example question of section two is seen in figure 5. The respondent is tasked to pick the map for which the method of visualisation fits the data best. This section tests the respondents' ability to distinguish between extensive and intensive measures in a different way, as extensive measures are best visualised using a proportional symbol map and intensive measures are best visualised using choropleth maps. In this section the order of questions is once again randomised but the position of the maps is always the same, the choropleth map on the left and the proportional symbol map on the right. This was done in order to not unnecessarily confuse the respondents. For this section a smaller geographical scale was chosen, namely that of the province of Utrecht, to enhance readability and make the section distinctly different from the previous section.

After the two main sections the respondents were asked to report their GIS experience and cartographic knowledge. First the respondents were asked to rate their GIS experience on a four part scale; 'laymen: never used GIS', 'beginner: can use basic GIS functions', 'trained: formally trained by a GIS course' and 'expert: used GIS for years'. These expertise categories were previously successfully used by van Ark (2022) and Nyamsuren et all. (2022). Then the respondents were asked to what extent they were familiar with cartographic rules regarding choropleth and proportional symbols maps. The participants had to answer on a 5-point Likert scale ranging from 'not at all familiar' to 'extremely familiar'. These questions were explicitly asked at the end of the survey to prevent any prior knowledge about the survey from skewing the results.

Respondents

The most important way this study can expand upon van Ark's research is by creating more data, specifically for users with less GIS experience and cartographic knowledge. Van Ark (2022) has already gathered a good amount of data on experts but his research lacks enough data on beginners and trained users to create a meaningful comparison between the groups. Therefore it would be best suited for this research to focus on getting a good amount of data on the beginners and trained groups. As such in this research the survey was spread to all first, second and third year bachelor students in the field of human geography and spatial planning of the Utrecht University. Some of these students will have little to no experience with GIS at all, whereas others might have had one or two courses on GIS and would be considered beginners and some might even be quite familiar with cartographic rules and have worked with GIS before and could consider themselves to be part of the trained group. The survey was distributed online using Qualtrics, a web-based surveying tool. All bachelor students were invited to join the survey through pre-existing WhatsApp groups as that was the most efficient way to reach the majority of the students while safeguarding their anonymity.

Statistical analysis

The statistical tests are done with the latest version of IBM SPSS Statistics, version 28. First and foremost it is important to test whether the survey results gathered from this study can be meaningfully combined with the results previously gathered in van Ark's study. In order to ensure the results of both studies do not significantly differ a statistical test comparing the means will be performed. A Mann-Whitney U test is used to confirm that the distribution of percentage of questions answered correctly in the surveys is the same across both surveys. Thus showing significant correlation between the two surveys or not. If both surveys show significant correlation the results can be combined for further analysis, if however the surveys do not show significant correlation both surveys will be analysed separately from here onward with the aim to still provide meaningful results.

To test the assumption that both sections of the survey correlate a Pearson's r correlation test will be performed. The hypothesis here is that any respondent that performed well in the first section also did in the second section. This test is important to see whether both sections actually measure the same ability to distinguish between extensive and intensive measures. If the Pearson's r correlation test shows significant correlation both the section results can be combined for further analysis but it might still be interesting to look at them both individually.

The next step is to test whether our respondents performed better than randomly guessing each answer. In order to test against this hypothetical randomness a one-sample t test is performed against a hypothetical population of random guessers who would reach an accuracy of 33% in the first section and 50% in the second section. The result of this test will show if respondents performed significantly better than they would when randomly selecting answers.

Following this step every group of GIS experience and cartographic knowledge will be tested individually to see if they performed significantly different from each other. First a binomial test will be done for every question and every group. This should provide an even more detailed overview of the respondents' ability to distinguish between extensive and intensive measures. Then every group will be tested against each other using a Kruskal-Wallis test. This test will show whether there is significant difference between the groups. Furthermore post-hoc Mann-Whitney U tests are performed for more detail about exactly which groups differ from each other significantly. These post-hoc tests are done with a Bonferonni correction in order to maintain a high significance level.

Results

The results chapter provides the descriptive and inferential statistics on the data gathered during the research. This chapter begins with the descriptive statistics, it then discusses the combining of the datasets after which it will answer each of the three sub-questions in a separate section. Much of this chapter will follow a structure similar to that of van Ark (2022). Starting with binomial tests for each question and group and subsequent Kruskall-Wallis tests, this study complements that of van Ark by providing larger sample sizes in the less skilled groups. On top of that additional post-hoc testing is done with the data to add more depth and precision to the results of the research. As explained in the previous chapter, the two datasets first have to be combined and tested for their compatibility.

Descriptive statistics

The survey was spread to all first, second and third year students of the bachelor program of Human Geography and Spatial Planning at the Utrecht University. Out of these 79 students started the survey and 29 successfully finished the survey. Figure 6 shows the frequencies of the answers given on the question about GIS experience and cartographic knowledge.In the GIS experience question, only one respondent classified themselves as a layman, fifteen described themselves as beginners and thirteen as trained. As for cartographic knowledge, two participants said they were not at all familiar with the rules regarding choropleth maps and proportional symbol maps, eight respondents stated they were slightly familiar with the rules, ten responded with somewhat familiar and nine stated they were moderately familiar.

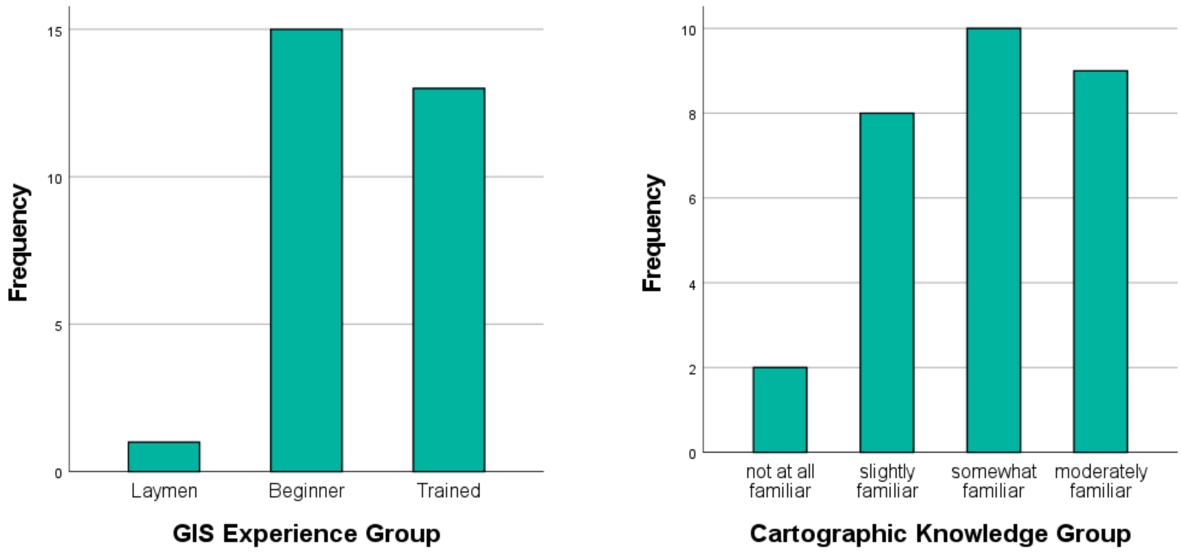

Figure 6. *Frequency graphs of each group of GIS experience and Cartographic Knowledge*

None of the respondents in this research classified themselves as experts in GIS or extremely familiar with cartographic rules, which was not entirely unexpected since all of the respondents were students, although the aim was to gather data on a larger number of laymen. This was partially due to a misunderstanding, as the bachelor programme has undergone some changes. The first GIS course is now part of the first year for every bachelor student whereas this was not the case a couple of years earlier. Therefore all of the bachelor students that were asked to participate had at least some experience with GIS. On top of that Van Ark (2022) has another explanation for the lack of laymen in his research, stating that the group indicated that they did not understand the task and therefore did not finish the survey as they felt that guessing the answers would not be beneficial for the research. It is possible that this phenomenon occurred in this study as well.

Figure 7 depicts the percentage of questions answered correctly, including standard errors, for each group in the GIS experience category on the left and the cartographic knowledge category on the right. Since only one respondent classified themselves as a layman in the GIS experience category, the first bar does not have much value. The others on the other hand do show some interesting results. Where the beginner group on average answered 48.2% of the questions correctly, the trained group answered on average 61.5% of the questions correctly. Although the graph seems to depict a pattern, it must be remembered that the first bar only depicts data for one respondent.

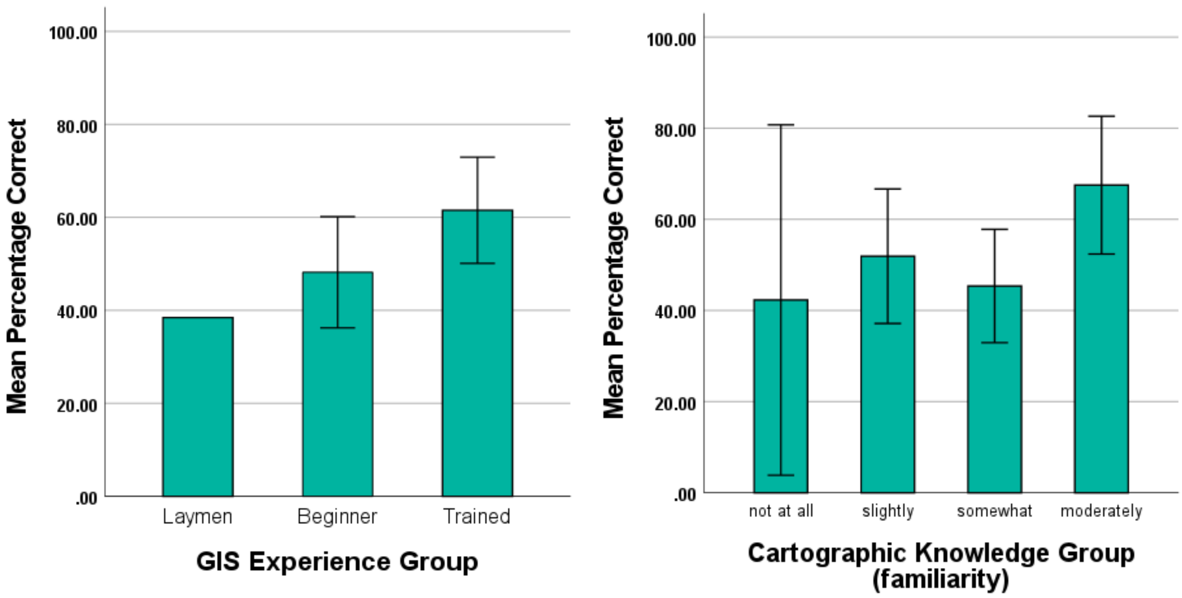

Figure 7. *Graphs depicting the mean percentage of questions answered correctly for each group of GIS Experience (left) and Cartographic Knowledge (Right).*

When looking at the same graphs for mean percentage of correct answers classified by cartographic knowledge in figure 7, the same pattern is less immediately obvious. Once again the lowest group, in this case not at all familiar, had very few respondents; only two of them said they were not at all familiar with the cartographic rules surrounding proportional symbol maps and choropleth maps. They had an accuracy of 42.3% among the 13 questions. The slightly familiar group notably outperformed the somewhat familiar group with an accuracy of 51.9% for the former and 45.4% for the latter. Finally the moderately familiar group scored better than all three other groups with an average 67.5% of the questions answered correctly.

Combining the datasets

Only very few respondents classified themselves as laymen in both studies, therefore the decision was made to combine the laymen and beginner groups into one group that from here on will be called the beginner group. Combining these groups is justified because they follow each other on an ordinal scale. By combining the groups more meaningful analysis with the different groups could be done as this leaves a total of 23 beginner, 23 trained and 18 expert respondents with both datasets merged. Where the new beginner group consists of respondents with no GIS experience and respondents with very little GIS experience.

As mentioned before, one of the goals of this research was to add more data to the already existing data gathered by van Ark (2022). It is assumed in this study that both datasets can be combined because both surveys used identical questions to measure the respondents' ability to distinguish between maps based on extensive and intensive measures. On top of that both studies had similar respondents, students in the department of geosciences at the Utrecht University and experts in the GIS field. The changes that have been made to the survey are considered minor and therefore are not expected to lead to significantly different results. To add strength to this assumption statistical tests were done with the results of both surveys.

First the datasets were added together and the mean accuracy of each of the groups were compared. Figure 8 depicts those accuracies for every group of GIS Experience and Cartographic Knowledge. Three things are noteworthy upon examining the figure. The respondents of the new dataset, gathered in this study, did not score better in any group than the respondents of the old dataset. However, the differences between the datasets seem small for every group (<5,5%), except the somewhat familiar group of the Cartographic Knowledge category (19.69%). Lastly as previously discussed there are no experts and extremely familiar respondents in the new dataset.

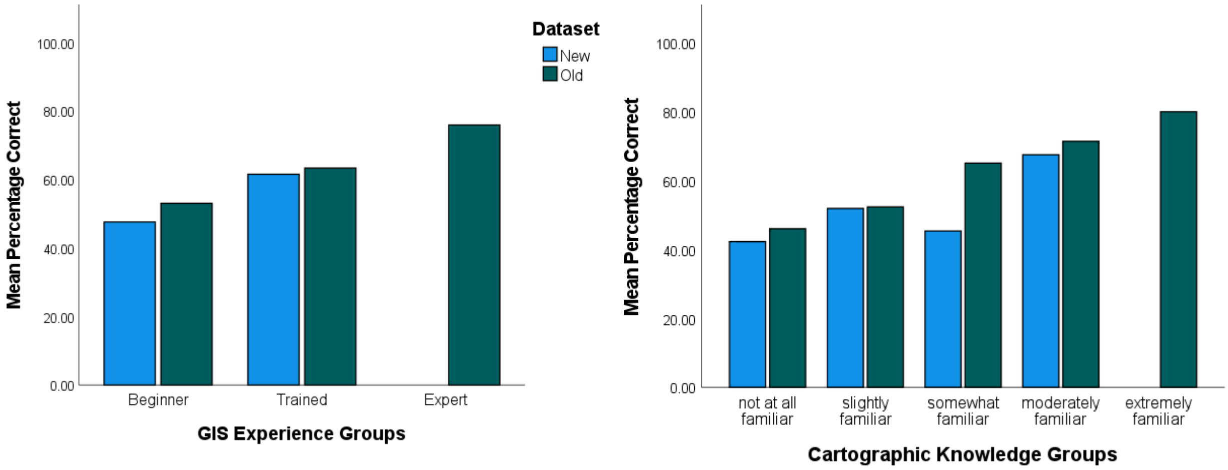

Figure 8. *The mean percentage of questions answered correctly for each group of GIS Experience (left) and Cartographic Knowledge (right) of both datasets. Blue bars depict the new dataset, data gathered in this study, green bars depict the old dataset, data gathered by van Ark (2022).*

Before any statistical test could be done, testing for normality was necessary as both datasets have a relatively small sample size and knowing the distribution of the data is required for choosing the appropriate statistical method. Thus, a Shapiro-Wilk test was performed and showed that the distribution of percentage of questions answered correctly departed significantly from normality (W(64) = 0.95, p = 0.016). Based on this result the assumption of a normal distribution that is imperative for parametric tests can not be made and therefore a non-parametric Mann-Whitney U test was performed to evaluate whether the percentage of questions answered correctly differed by dataset. The results indicated that there was no significant difference between the percentage of questions answered correctly of the dataset gathered in this research and the dataset gathered by van Ark's research (z = -0.58, p = .560).

Additional testing was done for the group in which the means stood out most, namely the somewhat familiar group in the cartographic knowledge category. This group contained ten respondents in the new dataset and twelve respondents in the old dataset. The respondents in the new dataset had an average accuracy of 45.4% whereas the respondents in the old dataset had an average accuracy of 65.1%. A Mann-Whitney U test was performed to evaluate whether the percentage of questions answered correctly differed by dataset. The results indicated that there was no significant difference between the percentage of questions answered correctly between the old and the new dataset in the somewhat familiar group (U = 87.00, p = .080). For the remainder of this research both datasets will thus be combined in statistical tests and analysis. However, it should be remembered throughout the rest of the research that the data originated from two different studies.

The mean percentage of questions answered correctly is based on the notion that both section one and section two of the survey correlate. To test this assumption a Pearson correlation coefficient was performed to evaluate the relationship between section one and section two of the survey. There was a significant moderate positive relationship between section one and section two (*r* ([62]) = .46, *p* = < .001). This result legitimises the assumption that a respondent that performs well in section one will also perform well in section two and vice versa and thus means that the combined results of performance in section one and two is a valid measurement to use in future statistical analysis.

For thoroughness this test was also performed for both individual datasets leading to similar results; There was a significant moderate positive relationship between section one and section two in the new dataset (*r* ([27]) = .46, *p* = .012). Additionally there was a significant moderate positive relationship between section one and section two in the old dataset (*r* ([33]) = .39, *p* = .022).

Test against randomness

To confirm that the respondents' ability to distinguish between extensive and intensive measures was not attributed to random guessing and their accuracy exceeded that of random guessing. Thereby answering the first sub-question, a one sample t-test was performed. This test was done separately for both the datasets because the hypothesised value of random guessing is different for both datasets, since in the new dataset the respondents had to answer eight 3-choice questions and five 2-choice questions and in the old dataset the respondents had to answer sixteen 3-choice questions and five 2-choice questions.

In the new dataset the test value is 39.54, the mean percentage of questions answered correctly when randomly guessing. A one sample t-test found that the respondents to the new survey scored better than a population based on random guessing (*t(29)* = 3.4, *p* = .002). Doing the same test for the old dataset with a test value of 37.05, which is the mean percentage of questions answered correctly when randomly guessing for that set, resulted in a similar result. The respondents to the old survey scored better than a population based on random guessing (*t(35)* = 7.9, *p* = <.001).

These results can be used to answer the first sub-question of this study: *To what extent is it possible for students and experts in the GIS field to distinguish between cartographic maps based on extensive and intensive measures?* The results of these one sample t-tests give strength to the hypothesis that students and experts in the field of GIS are capable of effectively distinguishing between extensive and intensive measures. In both surveys they did so significantly better than random guessing. The mean accuracy of the respondents in the new dataset was 53.8% compared to a random guessing value of 39.5%. The difference is even stronger for the old dataset, which is explained by the fact that it includes far more skilled GIS users. The mean accuracy of the respondents in the old dataset was 67.8% compared to a random guessing value of 37.1%.

Comparing the GIS experience groups

After the one sample t-tests a more detailed analysis of the data was done using a nonparametric binomial test for each question grouped by GIS experience and cartographic knowledge. Table 2 shows the results of this binomial test for the GIS experience groups. The population size of the groups is different per question because of the different versions of the survey, not every version was exactly as common. The table shows for each question and each group the population size, the amount of respondents who answered the question correctly and the probability value results of the binomial test against a test value associated with random guessing, 0.33 for section one and 0.50 for section two.

The binomial test was one-tailed and right-sided, meaning the resulting *p*-value will show whether the respondents performed significantly better than a population based on random guessing. From the table it is clear that the expert group performed significantly better on almost every question in section one with strong evidence ($p < .001$) for most questions. The only question on which the expert group did not perform significantly better than random guessing was question fourteen. This question did not necessarily seem to be experienced as more difficult than the other questions in the other groups. The trained and beginner groups had more difficulties with question one and two which in turn were not outliers in the expert group. The trained group performed significantly better on ten of the sixteen questions and the beginner group on only four of the sixteen questions in section one. In section two this difference between the groups is less obvious, there were however only five questions in this section and the previously performed Pearson’s correlation test showed significant correlation between the two sections. The beginners did significantly better than random guessing on only one question in section two and the other two groups did significantly better than random guessing on three of the five questions.

It seems that the increase in GIS experience has led to a higher accuracy among the respondents of the survey. To test whether this deemed result is significant a non-parametric Kruskal-Wallis test was conducted on each section individually and both sections combined.

	Beginner		*Trained*		*Expert*	
Section 1	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)
Q1	15 : 6	(.371)	16 : 9	(.047*)	18 : 11	(.013*)
Q2	15 : 3	(.217)	16 : 7	(.253)	18 : 14	(<.001***)
Q3	15 : 3	(.217)	16 : 6	(.442)	18 : 12	(.004**)
Q4	15 : 11	(.002**)	16 : 10	(.015*)	18 : 14	(<.001***)
Q5	16 : 14	(<.001***)	17 : 9	(.071)	18 : 16	(<.001***)
Q6	16 : 6	(.442)	17 : 10	(.025*)	18 : 12	(.004**)
Q7	16 : 7	(.253)	17 : 9	(.071)	18 : 11	(.013*)
Q8	16 : 13	(<.001***)	17 : 12	(.002**)	18 : 15	(<.001***)
Q9	15 : 5	(.585)	17 : 8	(.164)	18 : 11	(.013*)
Q10	15 : 6	(.371)	17 : 10	(.025*)	18 : 14	(<.001***)
Q11	15 : 5	(.585)	17 : 9	(.071)	18 : 13	(<.001***)
Q12	15 : 10	(.008**)	17 : 13	(<.001***)	18 : 15	(<.001***)
Q13	14 : 4	(.486)	16 : 10	(.015*)	18 : 17	(<.001***)
Q14	14 : 5	(.514)	16 : 9	(.047*)	18 : 9	(.102)
Q15	14 : 7	(.143)	16 : 12	(<.001***)	18 : 15	(<.001***)
Q16	14 : 5	(.514)	16 : 9	(.047*)	18 : 16	(<.001***)
Section 2	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)
Q20	23 : 17	(.035*)	23 : 20	(<.001***)	18 : 15	(.008**)
Q21	23 : 16	(.093)	23 : 20	(<.001***)	18 : 17	(<.001***)
Q22	23 : 9	(.405)	23 : 14	(.405)	18 : 14	(.031*)
Q23	23 : 10	(.678)	23 : 10	(.678)	18 : 13	(.096)
Q24	23 : 15	(.210)	23 : 21	(<.001***)	18 : 13	(.096)

Table 2. *Binomial test results for each question in section one for each GIS experience group against the expected probability of 0.33 in section 1 and 0.50 in section 2 for random choice. *p≤ 0.05, ** p≤ 0.01, ***p<.001*

First, a Kruskal-Wallis test was conducted to determine whether there is an effect of GIS experience on the percentage of questions answered correctly in section one of the survey. The results indicated a significant difference (K(2) = 11.371, *p* = .003). Therefore, the null hypothesis was rejected and it was concluded that there is a significant difference in the percentage of questions answered correctly in section one among the groups of beginners, trained individuals, and experts. Secondly, a Kruskal-Wallis test was conducted for section two of the survey. The results indicated a significant difference (K(2) = 7.671, *p* = .022). Therefore, the null hypothesis was rejected and it was concluded that there is also a significant difference in the percentage of questions answered correctly in section two among the groups of beginners, trained individuals, and experts. This result is in line with the expectations after doing the Pearson's correlation test and also gives an indication of the result of the final test. Finally, a Kruskal-Wallis test for both sections combined was conducted: the results indicated a significant difference ($K(2) = 13.112$, $p = .001$). Therefore, the null hypothesis was rejected and it was concluded that there is a significant difference in the percentage of questions answered correctly in both sections combined among the groups of beginners, trained individuals, and experts.

After the Kruskal-Wallis tests that showed significant difference between the three groups, a post hoc Mann-Whitney U test was performed for each group to test which specific groups differ from each other. For this test the significance level was corrected using the Bonferroni correction to reduce the chance of making false positives. The significance level of $\alpha = 0.05$ was divided by the three comparisons: beginner-trained, beginner-expert, and trained-expert, leading to a new significance level of $\alpha = 0.017$.

First, a Mann-Whitney U test was performed to assess whether the percentage of questions answered correctly differed significantly between the beginner ($n1 = 23$) and trained ($n2 = 23$) groups. The results indicated no significant difference between the beginner and trained groups ($U = 174$, $z = -1.99$, $p = .047$). A second Mann-Whitney U test to assess whether the percentage of questions answered correctly differed significantly between the beginner ($n1 = 23$) and expert ($n2 = 18$) groups did indicate a significant difference between the beginner and expert groups ($U = 73$, $z = -3.53$, $p < .001$). The third Mann-Whitney U test between the trained ($n1 = 23$) and expert ($n2 = 18$) groups indicated no significant difference between the trained and expert groups ($U = 136$, $z = -1.86$, $p = .063$).

Although two of the three Mann-Whitney U tests indicated no significant difference between the beginner and trained and the trained and expert groups, the tests did show significant difference between the beginner and expert groups. These test results combined with the Kruskal-Wallis test and the binomial tests are used to answer the second sub-question of this study: *To what extent is the ability to distinguish between cartographic maps based on extensive and intensive measures influenced by GIS experience?* The results give strength to the hypothesis that students and experts in the field of GIS can use GIS experience to effectively distinguish between extensive and intensive measures. The group with the most GIS experience, namely the expert group, had a significantly higher accuracy of 75,9% than the group with the least GIS experience, the beginner group with 49.3%. The middle group had an accuracy of 62.3% which was not significantly different from the beginner or the expert groups. Overall the three groups show a strong positive trend between increasing accuracy and increasing GIS experience.

Comparing the cartographic knowledge groups

As mentioned before a nonparametric binomial test was also performed for the cartographic knowledge groups, the results are shown in Table 3. The population size of the groups is different for some questions due to the previously explained effect of multiple versions of the survey. As with the earlier table on GIS experience table 3 also shows for each question and each group the population size, the amount of respondents who answered the question correctly and the probability value results of the binomial test against a test value associated with random guessing, 0.33 for section one and 0.50 for section two. The binomial test was one-tailed and right-sided, meaning the resulting p-value will show whether the respondents performed significantly better than a population based on random guessing.

	Not at all familiar		*Slightly familiar*		*Somewhat familiar*		*Moderately familiar*		*Extremely familiar*	
Section 1	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)
Q1	4 : 0	(.202)	4 : 3	(.108)	17 : 6	(.511)	19 : 14	(<.001***)	5 : 3	(.205)
Q2	4 : 0	(.202)	4 : 1	(.599)	17 : 8	(.164)	19 : 11	(.022*)	5 : 4	(.044*)
Q3	4 : 2	(.401)	4 : 0	(.202)	17 : 5	(.489)	19 : 10	(.061)	5 : 4	(.044*)
Q4	4 : 2	(.401)	4 : 4	(.012*)	17 : 14	(<.001***)	19 : 12	(.007**)	5 : 3	(.205)
Q5	3 : 2	(.255)	5 : 5	(.004**)	18 : 14	(<.001***)	20 : 14	(<.001***)	5 : 4	(.044*)
Q6	3 : 2	(.255)	5 : 1	(.468)	18 : 9	(.102)	20 : 12	(.012*)	5 : 4	(.044*)
Q7	3 : 3	(.036*)	5 : 2	(.532)	18 : 9	(.102)	20 : 9	(.182)	5 : 4	(.044*)
Q8	3 : 1	(.699)	5 : 5	(.004**)	18 : 15	(<.001***)	20 : 15	(<.001***)	5 : 4	(.044*)
Q9	4 : 2	(.401)	6 : 2	(.642)	17 : 6	(.511)	18 : 10	(.041*)	5 : 4	(.044*)
Q10	4 : 2	(.401)	6 : 3	(.313)	17 : 10	(.025*)	18 : 11	(.013*)	5 : 4	(.044*)
Q11	4 : 0	(.202)	6 : 3	(.313)	17 : 8	(.164)	18 : 13	(<.001***)	5 : 3	(.205)
Q12	4 : 1	(.599)	6 : 4	(.097)	17 : 13	(<.001***)	18 : 16	(<.001***)	5 : 4	(.044*)
Q13	5 : 3	(.205)	5 : 1	(.468)	16 : 10	(.015*)	17 : 12	(<.001***)	5 : 5	(.004**)
Q14	5 : 3	(.205)	5 : 0	(.135)	16 : 5	(.558)	17 : 11	(.007**)	5 : 4	(.044*)
Q15	5 : 2	(.532)	5 : 3	(.205)	16 : 12	(<.001***)	17 : 13	(<.001***)	5 : 4	(.044*)
Q16	5 : 4	(.044*)	5 : 5	(.004**)	16 : 8	(.120)	17 : 13	(<.001***)	5 : 5	(.004**)
Section 2	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)	N : Correct	(*p* -value)
Q20	5 : 3	(.500)	9 : 8	(.020*)	22 : 15	(.067)	23 : 22	(<.001***)	5 : 4	(.188)
Q21	5 : 4	(.188)	9 : 7	(.090)	22 : 17	(.009**)	23 : 20	(<.001***)	5 : 5	(.032*)
Q22	5 : 0	(.466)	9 : 3	(.254)	22 : 14	(.143)	23 : 17	(.018*)	5 : 3	(.500)
Q23	5 : 1	(.313)	9 : 3	(.254)	22 : 11	(.500)	23 : 14	(.203)	5 : 4	(.188)
Q24	5 : 3	(.500)	9 : 7	(.090)	22 : 14	(.143)	23 : 20	(<.001***)	5 : 5	(.032*)

Table 3. *Binomial test results for each question in section one for each cartographic knowledge group against the expected probability of 0.33 in section 1 and 0.50 in section 2 for random choice. *p≤ 0.05, ** p≤ 0.01, ***p<.001*

In the cartographic knowledge category it seems less immediately obvious based on the table that each next group performed better than the previous. However, in ascending order the groups in section one performed significantly better on two, four, six, fourteen and thirteen questions than random guessing. A similar trend is visible in section two with, in ascending order, zero, one, one, four, and two questions answered significantly better than the population based on random guessing. Three of the cartographic knowledge groups are extremely small with five, nine and five respondents, including the last group ‘extremely familiar'. This is somewhat problematic because with smaller sample sizes it gets harder to find significant results. Most respondents, 45 out of 64, indicated that they were either a 3 (somewhat familiar) or 4 (moderately familiar) on the 5-point likert scale when asked about their familiarity with the cartographic rules regarding choropleth maps and proportional symbols maps.

Kruskal-Wallis tests were performed on each section individually and both sections combined to assess whether there are significant differences between the five groups. The first test to determine whether there is an effect of cartographic knowledge on the percentage of questions answered correctly in section one of the survey indicated no significant difference between the groups ($K(4) = 7.266$, $p = .122$). Therefore, the null hypothesis was accepted and it was concluded that there is no significant difference in the percentage of questions answered correctly in section one among the five different groups of cartographic knowledge.

A second Kruskal-Wallis test was conducted for section two of the survey. The results for this section did indicate a significant difference ($K(4) = 13.079$, $p = .011$). Therefore, the null hypothesis was rejected and it was concluded that there is a significant difference in the percentage of questions answered correctly in section two among the five groups of cartographic knowledge.

Contrary to grouping the respondents based on GIS experience, when grouping them based on cartographic knowledge there does seem to be a difference between section one and two. A Kruskal-Wallis test for both sections combined however did indicate a significant difference ($K(4) = 10.271$, $p = .036$). Therefore, the null hypothesis was rejected and it was concluded that there is a significant difference in the percentage of questions answered correctly in both sections combined among the five groups of cartographic knowledge.

After the Kruskal-Wallis test, post hoc Mann-Whitney U tests were performed for each group to test which specific groups differ significantly from each other. The significance level for this test was set to $\alpha = 0.005$ which is achieved using the Bonferroni correction to reduce the chance of false positives. Table 4 shows the results of the ten Mann-Whitney U tests comparing each pair of the cartographic knowledge groups. None of the resulting p-values are equal to or lower than the corrected significance level and therefore the concluding result of the tests is that none of the groups differ significantly from each other.

Comparison	U statistic	z-value	*p* -value
not at all familiar vs *slightly familiar*	17.0	-.738	.460
not at all familiar vs *somewhat familiar*	34.5	-1.284	.199
not at all familiar vs *moderately familiar*	20.0	-2.257	.024
not at all familiar vs *extremely familiar*	3.5	-1.892	.059
slightly familiar vs *somewhat familiar*	86.5	-.546	.585
slightly familiar vs *moderately familiar*	55.0	-2.039	.041
slightly familiar vs *extremely familiar*	9.0	-1.804	.071
somewhat familiar vs *moderately familiar*	181.0	-1.639	.101
somewhat familiar vs *extremely familiar*	28.0	-1.690	.091
moderately familiar vs *extremely familiar*	39.5	-1.083	.279

Table 4. *Mann-Whitney U test results for each pairwise comparison between the five groups of cartographic knowledge. None of the p values indicate a significant difference between the groups when using a corrected significance level of α = 0.005.*

This result seems somewhat contradictory to the previous Kruskal-Wallis test, the contradiction is likely the result of the small sample sizes of the groups ‘not at all familiar’, ‘slightly familiar’, and ‘extremely familiar’. Additionally this result combined with the previous Kruskal-Wallis tests and binomial tests are used to answer the third sub-question: *To what extent is the ability to distinguish between cartographic maps based on extensive and intensive measures influenced by cartographic knowledge?* The results seem to reject the hypothesis that students and experts in the field of GIS can use cartographic knowledge to effectively distinguish between extensive and intensive measures. The group with the highest cartographic knowledge had an accuracy of 80%, which due to the small sample sizes of both groups was not significantly higher than the group with the lowest cartographic knowledge which had an accuracy of 44.5%.

Every next group in ascending order did have a higher accuracy than the ones before but the Mann-Whitney U tests showed no significant difference between any of the groups. We must conclude that there is a visual positive trend between increasing accuracy and increasing cartographic knowledge. However, there is not enough evidence from this survey to prove a significant influence of cartographic knowledge on the ability to distinguish between cartographic maps based on extensive and intensive measures.

Discussion

This study used an online survey to gather the data that has been analysed in detail. The results of the study indicated that the respondents were successful in distinguishing between extensive and intensive measures in cartographic maps. On top of that the influence of GIS experience and cartographic knowledge on this ability to distinguish were tested. GIS experience proved to have a significant influence whereas there was not enough evidence to say the same for cartographic knowledge. In this chapter a reflection on the research process is provided by discussing the limitations and potential consequences of this study and study design. The chapter includes interpretation of the results and some recommendations for future research on the subject.

The results of the survey are in line with the expectations as well as the claims of Scheider and Huisjes (2019) who claimed that for a skilled analyst it is intuitively clear that when aggregating two areas some measures can simply be summed up whereas other measures need to be weighted to arrive at a reliable estimate. This study not only confirmed that it is indeed possible for GIS users to distinguish between those aggregation operations but also that those users with more experience were significantly better at it. These results are also in line with those of Nyamsuren et al. (2022), who also found evidence that skilled GIS users are able to use analytical skills to distinguish between cartographic maps based on certain concepts, in their study two of the core concepts of spatial information.

Somewhat unexpected however, were the uncertain results on the influence of cartographic knowledge. No significant correlation was found between increasing cartographic knowledge and the ability to distinguish between maps based on extensive and intensive measures. These results were unexpected but could be explained through a number of reasons. First, the small sample size of some of the groups makes meaningful statistical analysis hard, the fact that these groups were so small in itself was wholly unexpected as the expectation was that an even range of GIS experience would also correlate with an even range of cartographic knowledge. This expectation proved to be false and that in itself is an interesting outcome. Secondly the Dunning Kruger effect could have influenced these results, it is however impossible to measure the exact influence of this effect and its existence can only be acknowledged.

The results of this study build on existing evidence for the effectiveness of core concepts that allow researchers to think about and discuss spatial information. The study provided evidence that extensivity and intensivity are intuitively understood by GIS users and especially by experienced GIS users. The concepts are also widely used in other scientific fields and would therefore be well suited for transdisciplinary approaches. In line with the work of Kuhn (2012). These concepts are not just suited for the social sciences but even find their origins in physics and chemistry. Future studies should focus on the ability of researchers from other fields to distinguish between cartographic maps based on extensive and intensive measures. Such research could provide an answer to the hypothesis that extensivity and intensivity are useful concepts for transdisciplinary research. By providing answers, it would also provide additional context to the relevance of adding extensivity and intensivity to the list of core concepts for spatial information.

Furthermore some of the limitations of this study should be acknowledged. First the survey allowed respondents to self-report their GIS experience and their knowledge of the rules surrounding proportional symbol maps and choropleth maps. By measuring these attributes in such a way the researcher loses control over these parameters. It is impossible to check the validity of these answers afterwards and measuring the experience and knowledge of the respondents in this way opens up the possibility that they were influenced by effects such as the Dunning-Kruger effect. Therefore I suggest that future research should use different methods to measure the respondents's experience and knowledge. An example could be by asking some basic questions about GIS and using those questions as a proxy for GIS experience.

Additionally it should be noted that an online survey comes with a few limitations that should be discussed. One such limitation is the fact that the researcher has no control over a number of variables, for instance the resources and environment which the respondent has used when answering each question. It is possible that the respondents have used the internet or other people either online or offline as a helpline which could lead to unreliable results. This shortcoming was combated by giving the respondent as little information as possible as to what the research was about. Furthermore there were no outliers in the time it took each respondent to fully complete the survey, each respondent took between 5 and 9 minutes. This leads to the assumption that no helplines were used. However, it is impossible to completely rule out the possibility that respondents used helplines.

It is hard to say whether the results of this study can be generalised to the entire GIS user population. Since most of the beginner and trained respondents were students from specifically the bachelor Human Geography and Spatial Planning at the University of Utrecht. This is quite a homogenous group, most of these students have followed similar GIS tutorials and lectures and it is possible that other students using GIS have acquired more or less skills that influence their ability to distinguish between extensive and intensive measures on cartographic maps. The experts that were part of this study are however a more heterogeneous group. They were contacted through online platforms such as LinkedIn and Reddit. These platforms give access to a wide range of GIS users from around the world. Future studies should provide evidence that the findings in this study can be replicated and generalised among the bigger GIS user population especially for the beginner and trained groups.

Conclusion

The overall goal of this thesis was to find to what extent GIS users could distinguish between representations of extensive and intensive quantities on cartographic maps. Additionally some concepts that were expected to influence this ability positively were introduced and analysed. The goal of these concepts was to give some context on how GIS users are able to recognize the main concepts and allow for a meaningful comparison between different experience and knowledge levels of GIS users. The main research question that was formulated to achieve this goal was: *To what extent can students and experts in the GIS field use GIS experience and cartographic knowledge to distinguish between maps based on extensive and intensive measures?*

The research question was answered using three sub-questions each answering a part of the main research question. These sub-questions have been answered in detail in the results chapter. First the analysis showed that the respondents in both of the surveys scored significantly better than a random guessing population. Thereby supporting the hypothesis that students and experts in the field of GIS are able to effectively distinguish between extensive and intensive measures on cartographical maps and answering the first sub-question. Second additional testing between the groups of beginner, trained and expert showed significant difference in accuracy between the groups. The experts scored significantly better than the beginners. These tests support the hypothesis that there is a positive correlation between GIS experience and the ability to effectively distinguish between extensive and intensive measures on cartographical maps and give a meaningful answer to sub-question two. However, it should be noted that there was not enough evidence to show a similar significant difference between the beginner and trained groups or between the trained and expert groups. It should also be noted that even though the experts scored significantly better than the beginner group, the beginners still proved to have certain intuitive notions with which they were able to distinguish between the extensive and intensive measures. Finally the same testing was done between groups based on the cartographic knowledge variable. These tests showed a similar positive trend but also revealed that there is not enough evidence from this survey to prove a significant influence of cartographic knowledge on the ability to distinguish between cartographic maps based on extensive and intensive measures.

To answer the main research question, the three sub-questions are answered and together lead to the conclusion that this study has provided evidence to support the idea that GIS users can distinguish between extensive and intensive measures on cartographic maps and that GIS experience can be used to make this distinction. Further research on extensivity in GIS should be done to find out more about what influences the intuitive ability to distinguish between extensive and intensive measures.

This research has, regardless of the discussed limitations, provided some strong evidence that supports the goals of this study. Some important findings in this research will further the study of the concept of extensivity and could eventually lead to successfully introducing the concept in GIS software. In addition, by proving that the concept is indeed part of cartographic maps and can be recognized by GIS users, this research has provided a bridge between scientific disciplines. Those disciplines in which the concepts of extensive and intensive measures have been widely discussed and normalised such as physics and chemistry could use these concepts to discuss phenomena with colleagues of the GIS discipline. This was in part the reasoning behind creating core concepts for GIS by Kuhn (2012), and therefore it can be argued that the concepts extensivity and intensivity should be added to those core concepts.

This chapter will conclude with one more recommendation for future research. Specifically to add on to this study, a meaningful study could be done to find out what exactly influences the ability to distinguish between cartographic maps based on extensive and intensive measures. A similar survey could be combined with qualitative interview style methods to discover what strategies and skills respondents use to answer similar questions. This would not only provide additional variables that could prove influential on the ability to distinguish between extensive and intensive measures, it would also strengthen the survey data by providing context on the strategies used by beginners and experts. Additionally this could provide data for a meaningful regression analysis that includes all the predictor variables discovered in the study.

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Appendix 1 - Overview of measures used in survey

Question - Measure type - Description

Section 1

1a ext Total ha of surface water per municipality
1b ext Number of residents per municipality
1c int Reported instances of vandalism per 1000 inhabitants per municipality

2a ext Number of businesses in finance and real estate per municipality
2b int Houses occupied in percentage per municipality
2c ext Total ha of land per municipality

3a int Share of rental homes in percentage per municipality
3b ext Number of men per municipality
3c int Mean distance towards nearest cinema for inhabitants in km per municipality

4a int Average number of primary schools within 5km for inhabitants per municipality
4b ext Quantity of cars per municipality
4c ext Number of ICT and communication businesses per municipality

5a ext Number of households per municipality
5b ext Recreation and culture businesses per municipality
5c int Mean yearly electricity usage per home per municipality

6a int Average distance to the closest hospital for inhabitants per municipality
6b ext Number of businesses in commerce and energy per municipality
6c int Mean house prices in thousands of euros per municipality

7a int Share of homes owned by housing corporations in percentage per municipality
7b int Average distance to nearest train station for inhabitants per municipality
7c ext Number of deaths in 2017 per municipality

8a ext Number of people with a state benefit pension (AOW) per municipality
8b int Reported sexual and violent crimes per 1000 inhabitants per municipality
8c ext Quantity of cars older than 6 years per municipality

9a ext Number of people that receive unemployment benefits per municipality

9b int Average distance to nearest fire station for inhabitants per municipality
9c int Share of people aged between 45 and 65 in percentage per municipality

10a int Share of homes built before 2000 in percentage per municipality
10b int Percentage of people with surinamese migration background per municipality
10c ext Number of births yearly per municipality

11a ext Size in ha of each municipality
11b int Share of owner-occupied homes per municipality
11c ext Number of women per municipality

12a ext Quantity of cars using any other fuel than petrol per municipality
12b ext Number of people with a personal income per municipality
12c int Share of unoccupied homes in percentage per municipality

13a int Mean income in euro per inhabitant per municipality
13b ext Number of businesses in agriculture and forestry per municipality
13c int Average number of people per household per municipality

14a int Reported theft crimes per 1000 people per municipality
14b ext Number of houses per municipality
14c int Average distance to closest primary school for inhabitants in metres per municipality

15a ext Total number of businesses per municipality
15b ext Quantity of motorbikes per municipality
15c int Mean yearly natural gas use per household in m3 per municipality

16a int Mean distance towards the closest supermarket for inhabitants in km per municipality
16b int Share of people with a low income (bottom 40%) in percentage per municipality
16c ext Number of cars younger than 6 years per municipality

Section 2

20 Average distance to the nearest cinema for inhabitants per municipality
21 Mean income in thousands of euros per income earner per municipality
22 Number of inhabitants per municipality
23 Number of motorbikes per municipality
24 Reported instances of theft per 1000 inhabitants per municipality

Appendix 2 - Screenshots of the full survey

Utrecht University

Welcome to this GIS concept study

This study aims to gain a deeper understanding of how maps are interpreted.
The test will consist of two short sections, where each of the questions within the section will be the same.
The entire survey should take around 10 minutes.

If you have any questions feel free to contact me.

Mick Raamsteeboers
m.raamsteeboers@students.uu.nl

→

Utrecht University

Informed consent for participating in online study on interpreting geospatial data

You are invited to participate in this research by Mick Raamsteeboers, bachelor student at Utrecht University. Your participation in this study is entirely voluntarily and you may withdraw at any time.
There is an optional reward of €5 available as a compensation for your time and effort. If you would like to get compensated, you are asked to leave your personal email address at the end of the survey. Your personal information will only be used for contacting you regarding this reward. If you want to remain anonymous you can choose not to add your email address at the end of the survey. An email will only be send to the participants that have produced valid and complete results. The purpose of this research is for a bachelor thesis, data gathered in this research will only be shared with the thesis supervisors.

If you have any questions or concerns, feel free to contact me via email: m.raamsteeboers@students.uu.nl

Do you consent to participating in this research study?

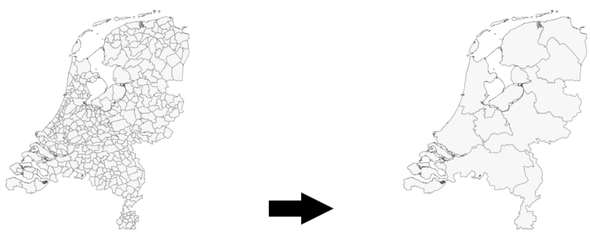
- ◯ Yes, I consent in participating
- ◯ No, I do not consent and will not be participating

Utrecht University

Section 1 - instructions

All maps shown for these questions depict data from CBS statline and depict information about the municipalities of the Netherlands over the year 2017, this is consistent for each map and does not change.

For each question in section 1 you will be asked to consider three maps. One of these three maps will be different from the other two, in terms of whether the following aggregation operation can be meaningfully applied to them. Assume that for each map you see your task is to aggregate data from Dutch municipalities to provinces. Your task will be selecting the map for which this aggregation operation is different.



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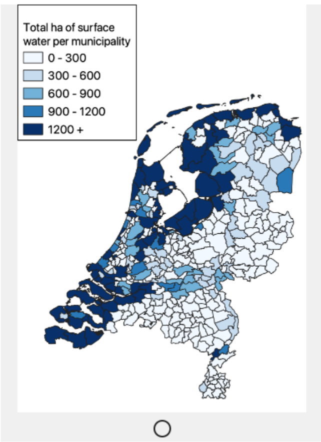
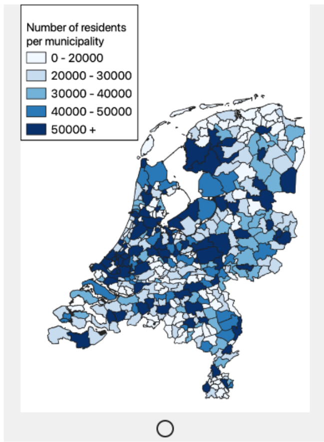
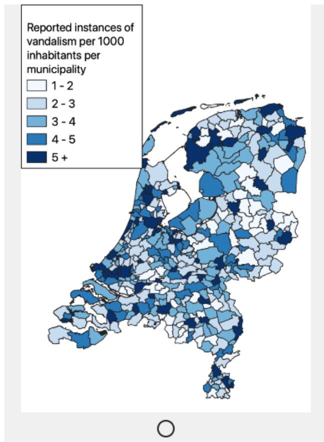
Which of the following maps is to be treated differently from the other two when aggregating regions?







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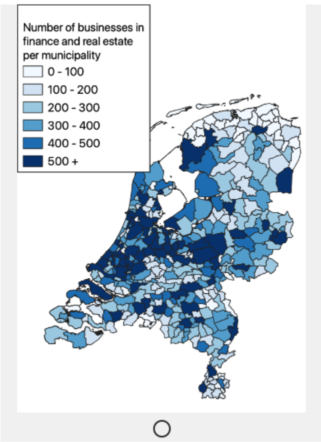

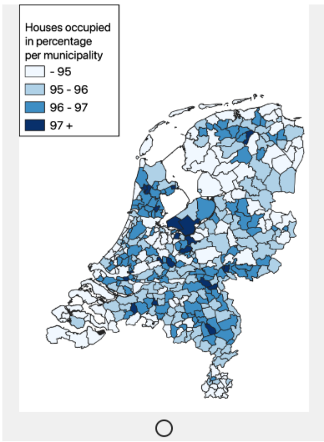

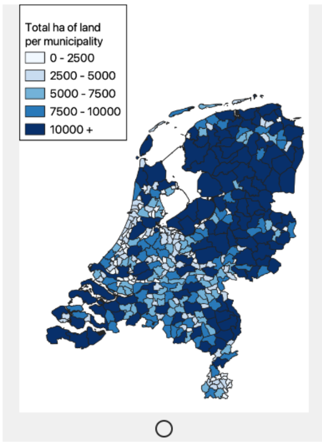

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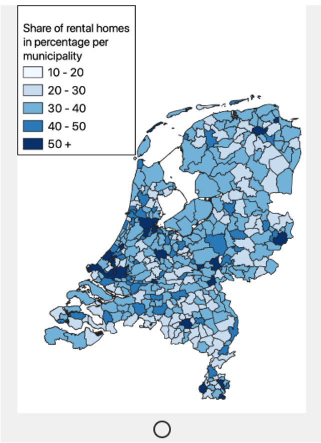

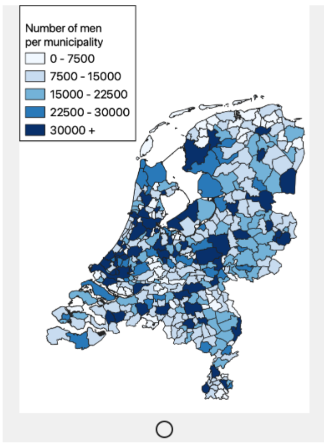

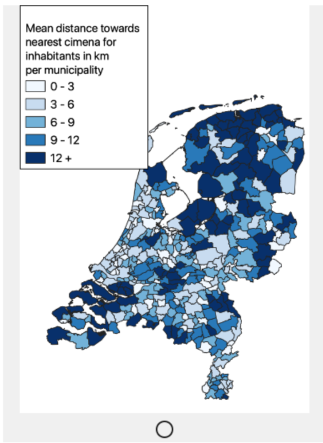

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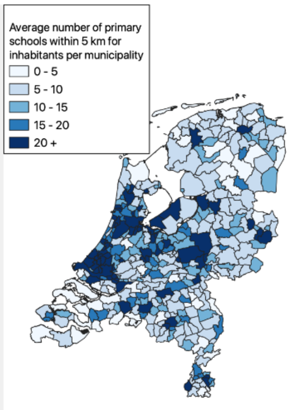

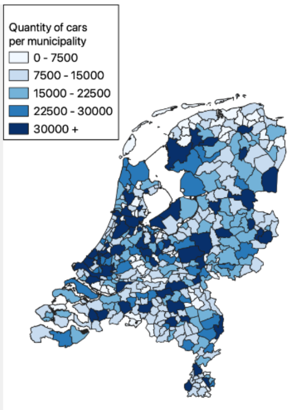

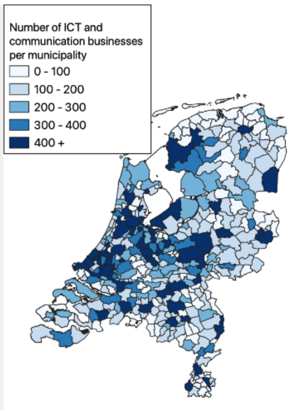

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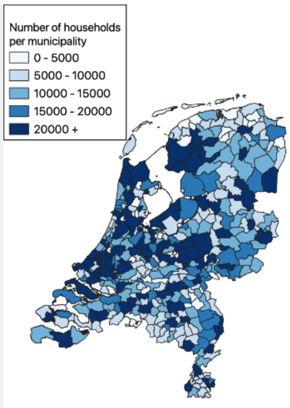

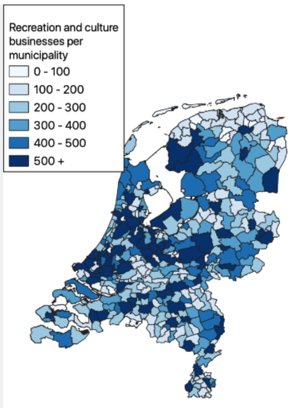

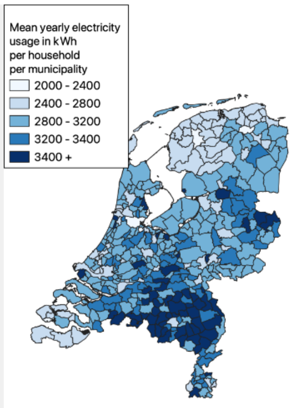

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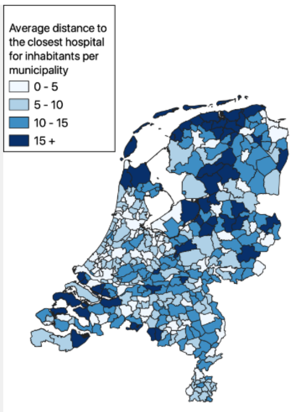

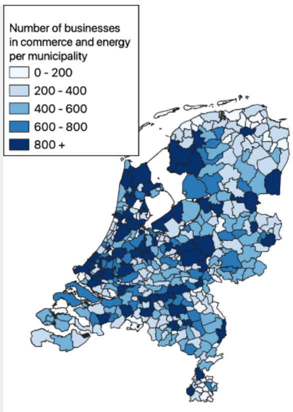

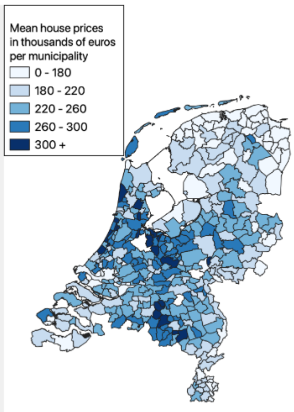

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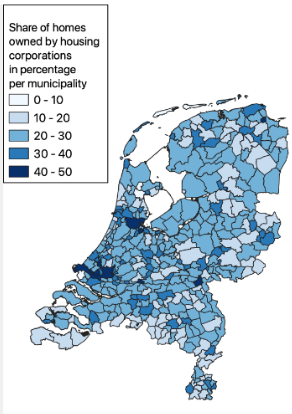

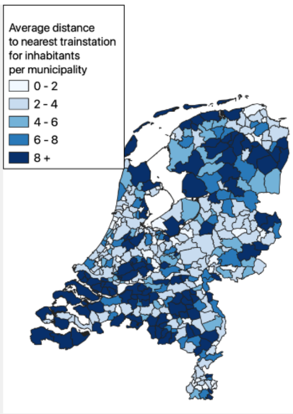

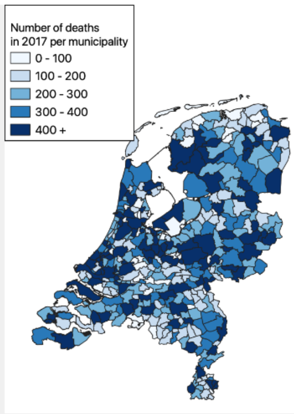

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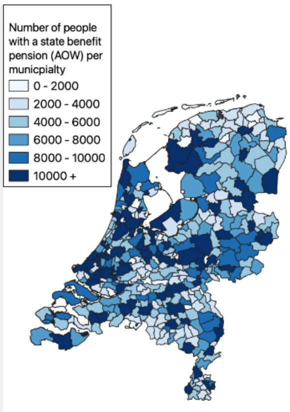

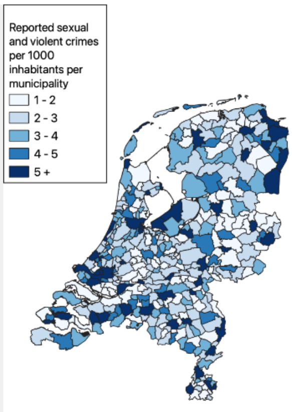

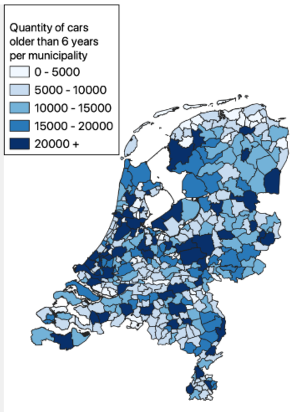

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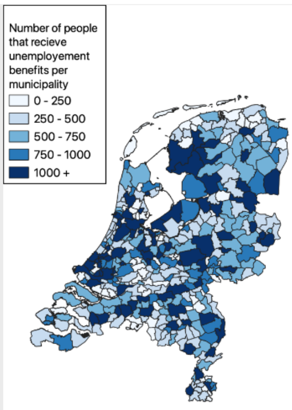

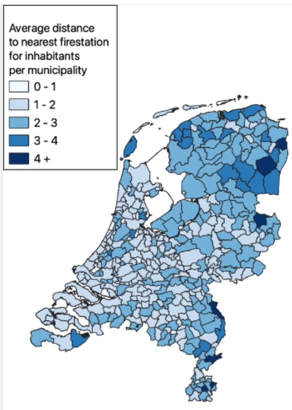

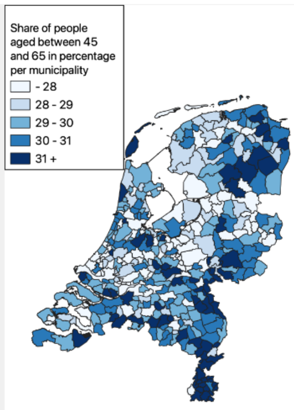

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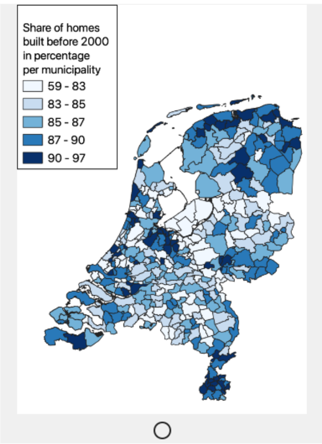
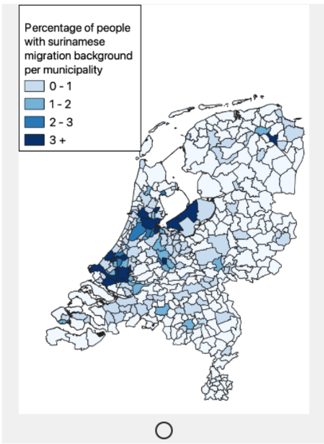
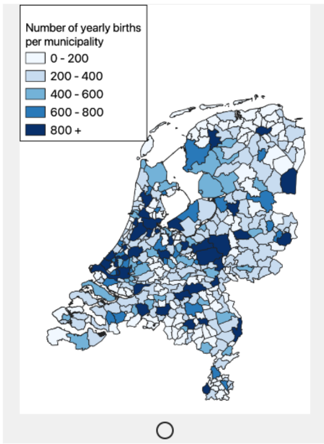
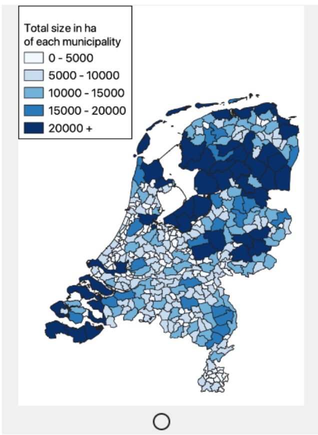
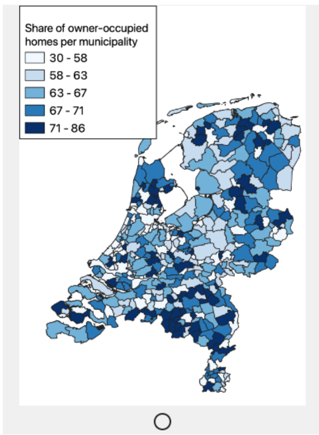


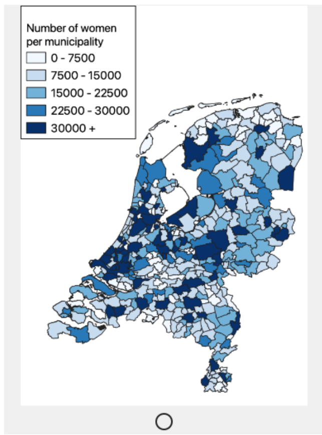




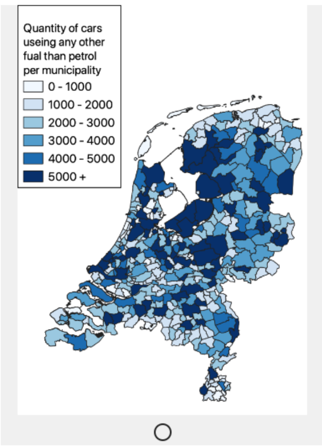
Which of the following maps is to be treated differently from the other two when aggregating regions?

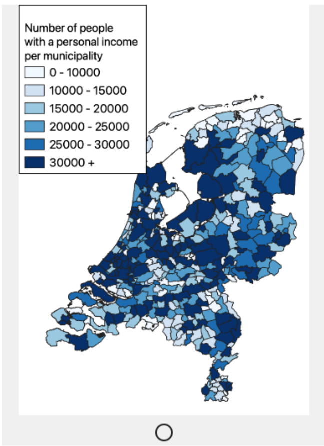


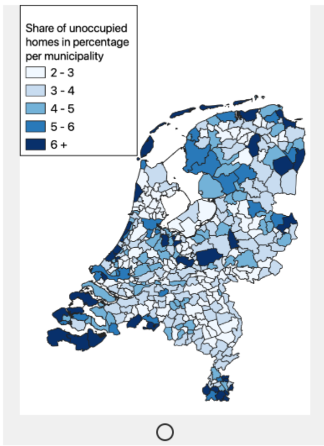




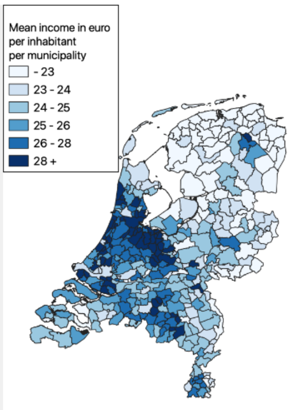
Which of the following maps is to be treated differently from the other two when aggregating regions?

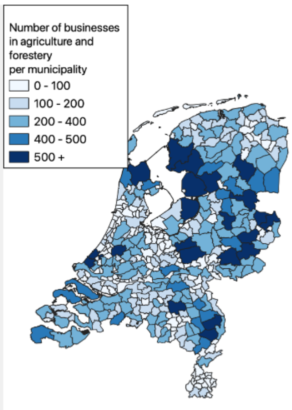


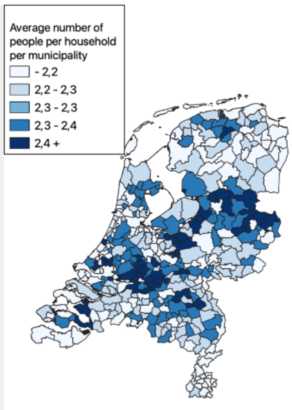




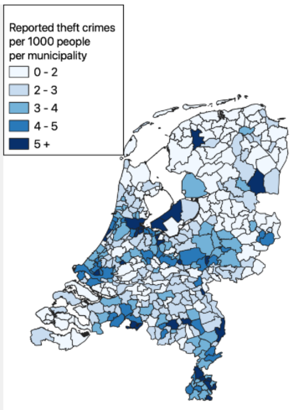
Which of the following maps is to be treated differently from the other two when aggregating regions?

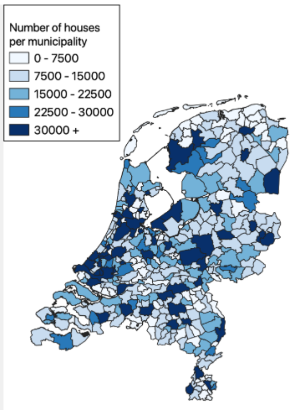


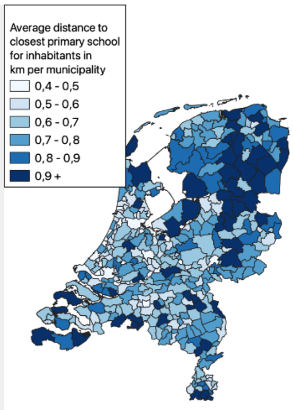




Which of the following maps is to be treated differently from the other two when aggregating regions?







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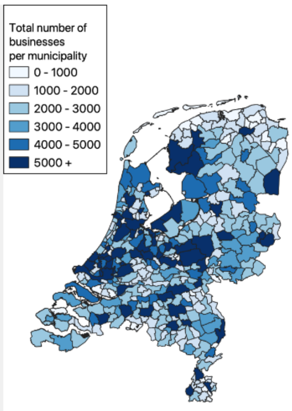
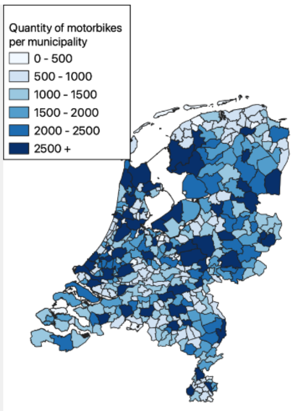
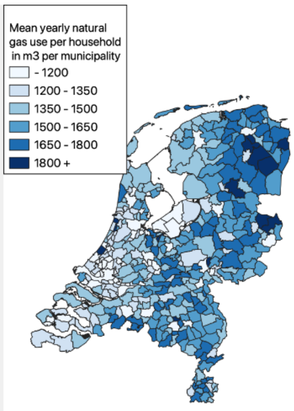
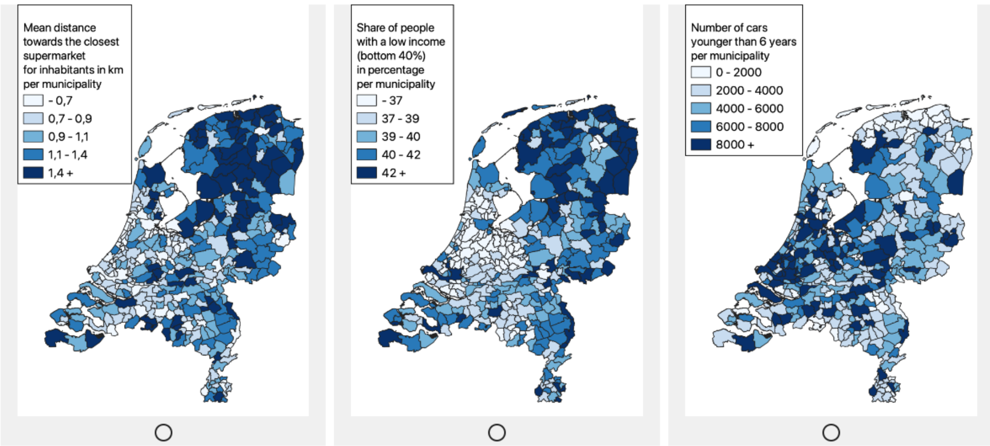






Which of the following maps is to be treated differently from the other two when aggregating regions?



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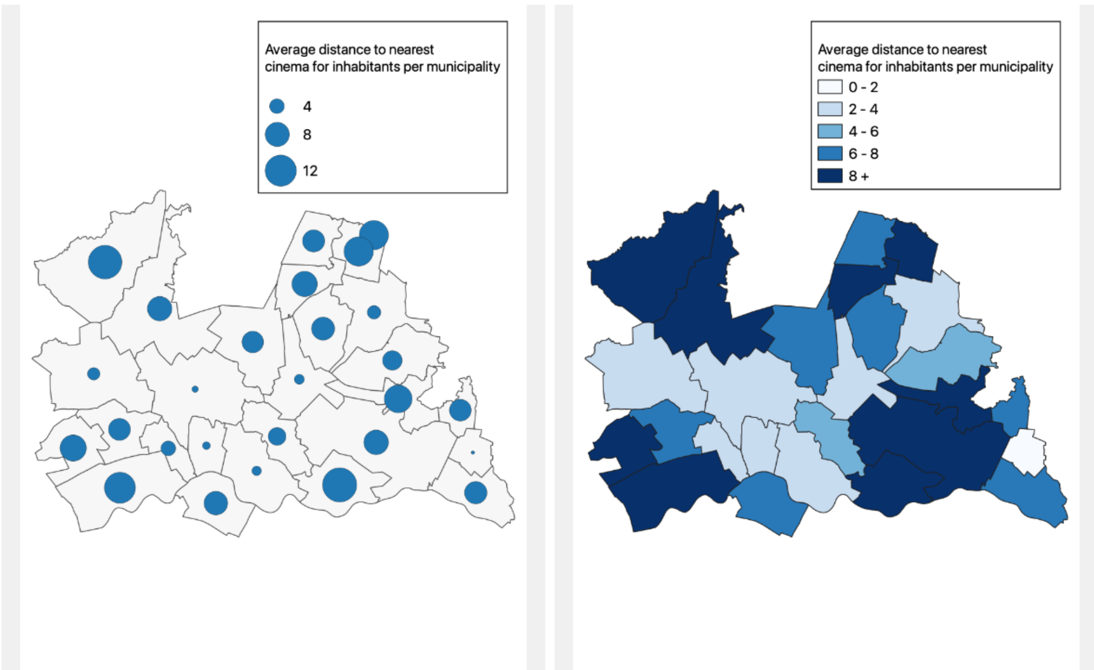
That was the end of the first section.

Section 2 - Instructions

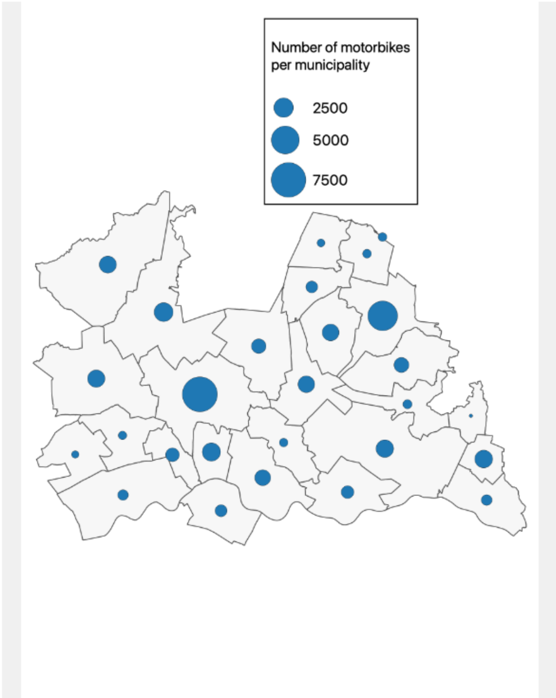
In each of the five questions in the following section you will see two maps visualizing the same data from CBS statline. You must pick the method of visualization that fits the data best.

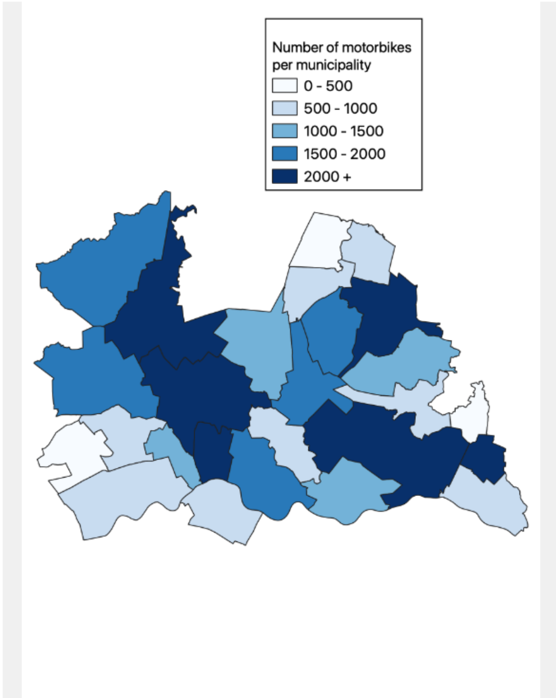
→

For which of these two maps does the method of visualization fit best for this data?

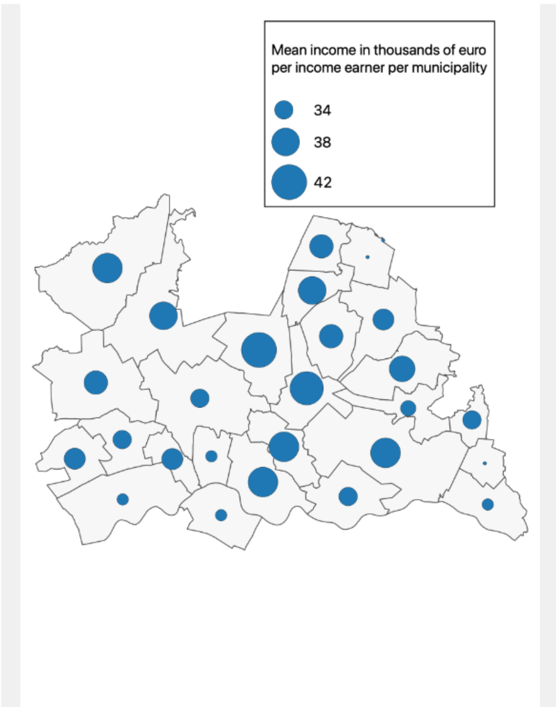


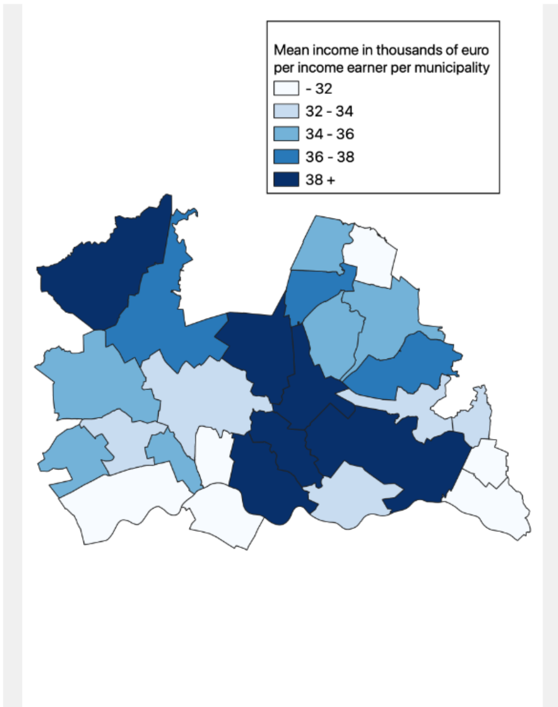
For which of these two maps does the visualization fit best for this data?



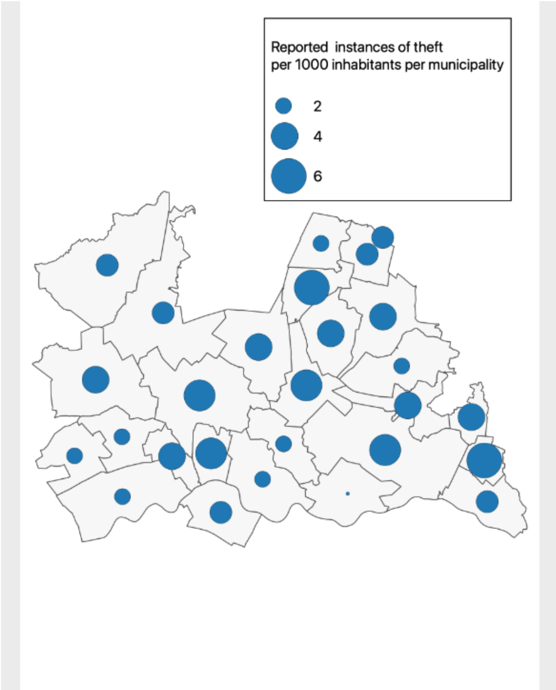


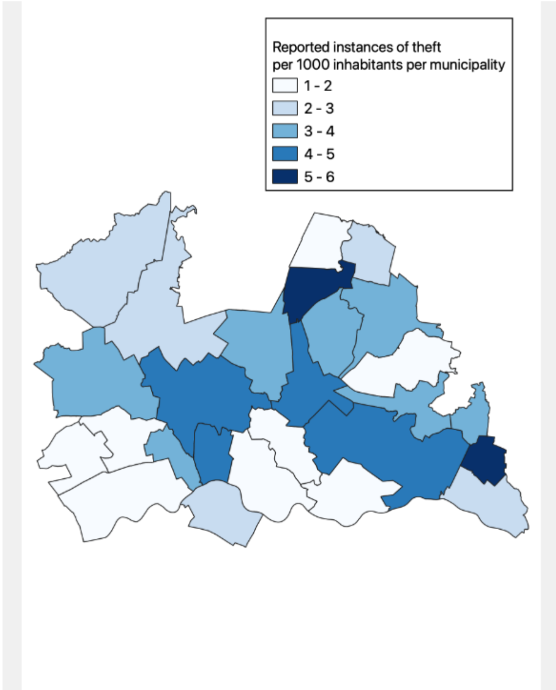
For which of these two maps does the visualization fit best for this data?



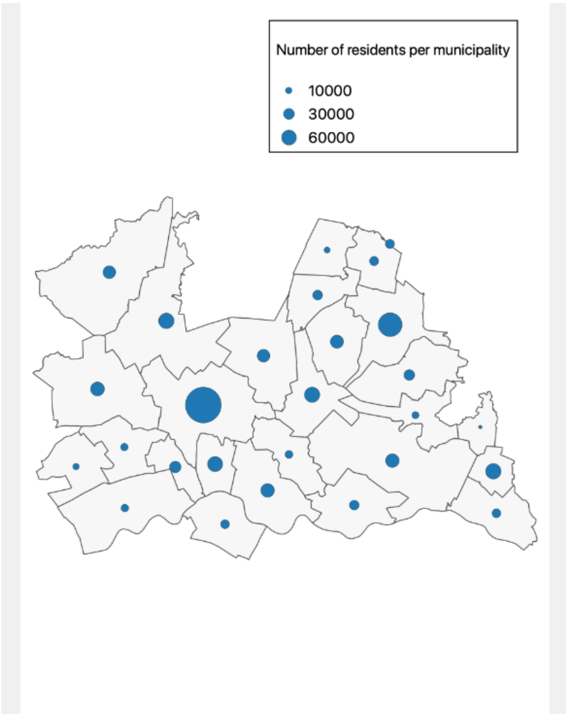


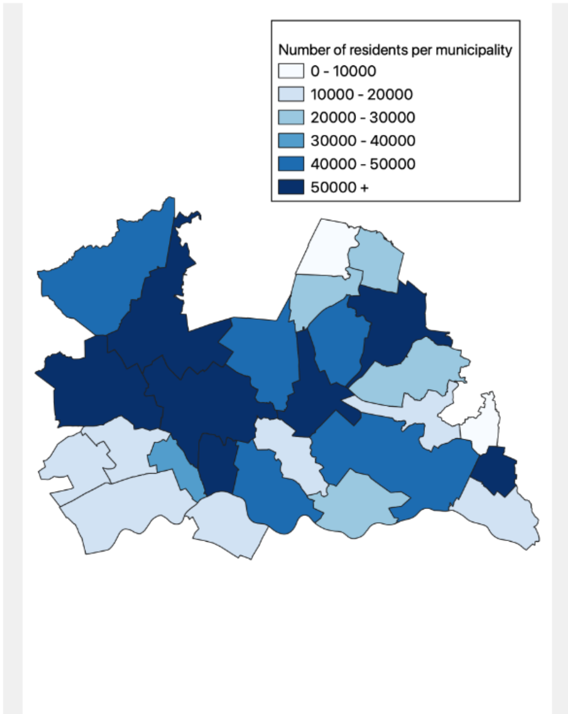
For which of these two maps does the visualization fit best for this data?





For which of these two maps does the visualization fit best for this data?





How familiar are you with using GIS?

- ◯ Laymen: never used GIS
- ◯ Beginner: can use basic GIS functions
- ◯ Trained: formally trained by GIS a course
- ◯ Expert: used GIS for years

To what extent are you familiar with cartographic rules regarding chloropleth maps and graduated symbol maps?

- ◯ 1 - not at all familiar
- ◯ 2 - slightly familiar
- ◯ 3 - somewhat familiar
- ◯ 4 - moderately familiar
- ◯ 5 - extremely familiar

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I would like to get compensated for participating in this study.

- ◯ Agree (You will be asked to leave your personal email address)
- ◯ Disagree

→

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We thank you for your time spent taking this survey.
Your response has been recorded.