



Materiality in Cartography A First Attempt to Evaluate its Usefulness

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Abstract

Materiality has gradually become a dimension of study in various fields. Social sciences have found in material culture a tool to study social relations. Cognitive sciences in the other hand, recognize material elements as agents in the cognitive process, under the concept of the embodied mind. Visual arts and design find in the use of materials a tool to shape human behavior, evoke emotions, and communicate messages. These fields are deeply intertwined with cartography and share with it the interest in processes as human cognition, communication techniques. Although the use of materials in cartography has been defined through a practical lens, there has been a growing interest in exploring other sensory dimensions through the materiality of maps. The aim of this study was to explore materiality in the cartographic process. A case study to be mapped and a conventional media map representing the topic were selected. Based on this, a material exploration process was conducted and two main materials were selected based on the symbolic relation to the topic and the physical characteristics convenient from a cartographic design perspective. A comparative user study was conducted with 23 participants who interacted with the conventional media map printed on paper and the alternative media map. Quantitative and qualitative data was collected to study the differences in the interaction and perspective of the participants towards both maps. A statistical analysis concluded that there was a statistically significant difference in 3 of the 6 comparison items. In addition, qualitative insights provided a broader understanding of the motivations behind the similarities and differences perceived by the users. The study provides a basis for exploring the possibilities of materials in cartography, in the mapper's experience, in the enhancement of messages in map communication, and in the experience and cognitive process of map-user interaction.

Keywords: materiality, affordance, sensory interaction, cartographic design.

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To the environmental activists killed for protecting their land and the
ones that still risk their lives everyday.

Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled: "Materiality in Cartography. A First Attempt to Evaluate its Usefulness"

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Vienna, 06.09.2023

Manuela Londoño Jiménez

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Chapter 1

Introduction

1.1 Introduction

Few attempts have been made to study the role of materiality in cartography, specifically its effect on the perception of users of maps. Although scholars have discussed the importance of the materiality of maps (Bunge, 1971; Edney, 2019), it remains to be analyzed how the use of different materials in map making might affect the interaction between users and maps. Although materiality is far from being a common variable of study in cartography, other academic fields consider materiality a fundamental dimension in their studies.

In the social sciences materiality has been in the spotlight for a couple of decades. It has been proposed that the materiality of objects and media shape society, culture, and the understanding and use of an object by an individual (H. A. Innis, 1951; Miller et al., 2005; Wagner, 2016). The concept of affordance (Gibson, 1966) has been closely connected to materiality, being understood as what an object enables in its use and how sometimes materials influence and allow for specific actions in the interaction of people with objects. Objects can also be seen as active elements that have their own agencies and are carriers of meaning (Bennett, 2010). Acknowledging the possibilities of materials and objects as active elements that shape interactions has led to a more conscious selection of materials in fields where the aim is to convey.

The selective use of materials acts as a design variable for communication in a wide range of disciplines like art, architecture and design. Creators and artists can place hidden messages conveyed by the selection of materials on their work, sharing meaning not only in the form of a piece but also in the faculty of the materials composing it (Lange-Berndt, 2015). In architecture, two buildings can share the same shape and be under the same conditions, but if one is constructed in concrete and the other in recycled wood, the perception of the viewer will not be the same, and it is not only the physical aspect but the concept behind the material. Although the potential of the use of materials has been widely recognized in different disciplines that involve interaction between objects and humans, materiality has not been frequently mentioned in cartography.

Materiality has not played a major role when it comes to cartography studies. Maps are often perceived as visuals and not as objects. Besides some interest in historical approaches to discover more about the context of the map, the status, the mapper and the techniques used (Pardo, 2021), materiality is rarely mentioned in cartography. Even though some cartography scholars have talked about maps as physical objects and the role of materiality on the messages maps aim to convey (Bunge, 1971; Edney, 2019; Wood, 2009), little attempts have been made to evaluate the effect of the materiality of maps.

Observing the role materiality has reached in other fields that overlap with cartography, it is relevant to ask ourselves about the potential of understanding materiality as a cartographic variable. Could materiality represent a factor that should be accounted for in the interaction between user and map, as it is considered in design between user and object? Or, could the conscious selection of materials in a map enhance a message that a map wants to convey, as it has been done by multiple artists in their artworks? (Lange-Berndt, 2015). Once we think about a map as an object can materiality guide the interaction people have with a map, as it has been theorized before (Wood, 2009)? To have an approximation to answers, it becomes fundamental to analyze the interaction of users with maps where materiality was acknowledged as part of the creative process.

1.2 Research Identification

Background, Literature Review

RO1 Explore the concept of materiality and its interpretation on different fields of study.

RQ1.1 How is materiality defined and understood in different fields?

RO2 Identify the relevance of materiality in social sciences and its use in art and design.

RQ2.1 How is materiality relevant and why has it been studied recently?

RQ2.2 How is materiality understood as a carrier of meaning?

RQ2.3 How has materiality been understood as an active element of communication?

Case Selection and Implementation

RO3 Explore the selection of materials in map design through the evaluation of a case study.

RQ3.1 Which materials could be related to the topic and the message the map aims to convey?

RQ3.2 In which ways do the materials relate and carry significance in the context of the map?

RQ3.3 Which materials represent a suitable alternative for the map creation?

RO4 Explore different possibilities for the acknowledgement of materiality in map making.

RQ4.1 How could the chosen materials be a part of the map?

Case Evaluation

RO5 Evaluate and analyze if the conscious selection and use of materiality in a map can change the perception a user has of the map.

RQ5.1 How does the user interact with the different types of maps (paper map and alternative material map)?

RQ5.2 Does the user report a difference on the perception of the maps? If so, how does this perception defer?

Chapter 2

Literature Review

This chapter presents some perspectives on how materiality is understood and approached in different academic fields. Furthermore, how the materials composing objects, artifacts, artworks, places, and in general the environment around us, play a role in various aspects and relationships that these fields study. The following literature review explores the relevance of the role of materials in the interaction, perception and understanding of people in their encounters with these physical elements. In addition, this section analyzes how the concepts and ideas discussed by scholars in these diverse fields could represent a potential branch of research in the realm of cartography, and how an integration of this knowledge in map making could be meaningful for cartographic interest.

2.1 Materiality as a Perspective in the Social Sciences

In the second half of the 20th century the paradigm of social sciences was expanded, once materiality became a significant focus. First, Gibson introduced the concept of affordances, as the potential actions in the interactions between an agent and its environment (Gibson, 1979). Object affordances are the actions that the object allows, for example an affordance of a functioning button would be to be pushed. After the concept of affordance was introduced, several scholars have been reshaping our understanding of the role of material objects in the social sciences domain. Following a materialist approach materiality in social sciences can be understood as the agency of objects through their material affordances to shape human behavior through human - object interaction (Lievrouw, 2014). Under a new scope, objects and their physicality stopped being interpreted as passive elements, to be perceived as actors with agency that can shape interactions, relations, and other immaterial aspects fundamental in the social sciences studies. Therefore, this new paradigm acknowledged a “tightly-interwoven relationship between the material and the symbolic” (Boczkowski & Lievrouw, 2007, p. 967).

The concept of materiality in social sciences and in material culture has been however, focused on the role of objects on society and cultures (Miller et al., 2005). Nevertheless some scholars like (Ingold, 2007) question the invisibilization of materials within materiality studies, as scholars mostly refer to

the role of ready made objects without giving materials composing the objects a major role in their analysis. Ingold proposes a new perspective on the understanding of things as active not because they have agency but because of the constant interaction they have with the environment. Building upon that vision, Ingold understands materiality as a changing characteristic that is “processual and relational” (Ingold, 2007, p. 1) then the materiality of objects and materials is shaped by their environment. However, besides the focus on materials from Ingold, some recognition has been given to materials as a relevant variable of the materiality of objects. In the field of media studies, scholars recognize the importance of the media, also understood as the material, on communication artifacts.

The concept of materiality in media studies has been formulated by scholars such as Innis and McLuhan. Innis recommends considering the physical properties of different media as responsible for the influence that they exert on societies and cultures. For instance, he proposes categorizing media and their qualities according to their potential impact on civilizations. Innis also notes the various biases inherent in different types of media. The concept of time bias is present in media that emphasize longevity, such as stone and clay, but limit ease of mobility in the spatial dimension (Innis, 1950). Religious and moral messages are often conveyed through these types of media, with the intention of withstanding the test of time. On the other hand, the space bias is attributed to lightweight media that can be easily transported but are vulnerable to potential destruction. Although this allows for communication on conquest and war issues by overcoming spatial constraints, the messages conveyed are transient and ephemeral (Innis, 1950). The previously mentioned analysis exemplifies how studying materiality can reveal signs of immaterial concepts such as social relations and cultural characteristics within the scope of social sciences.

Building upon the ideas of McLuhan, Wagner states that “Material needs no longer to be understood as a detachable carrier for a form or an idea, but can be regarded as indissolubly interwoven with it.” (Wagner, 2001, p. 27). Following this idea, materials are not just a medium for an idea but materials inherently hold significance through their characteristics, origin, symbology and more. Wagner draws a parallel between the duality of form and material and that of the body and soul. The discourse on body and mind, another dualism, has been recently questioned, this time in the field of cognitive sciences where the concept of materiality has emerged as a subject of interest.

2.2 Materiality as an Active Element in Cognitive Sciences

In the fields of cognitive sciences, recent discussions have risen regarding the understanding of human mind. Traditionally we limit the extent of the mind to the brain, with the rest being viewed as a response to preceding mental activities. Nevertheless, Lambros Malafouris with the proposal of the Material engagement theory, questions that definition of the mind. Building upon the concepts of embodiment and extended mind (Varela et al., 1991) Malafouris establishes a new analytical unit for cognitive processes where not only the brain is the focus but also the body and the surrounding environment (Malafouris, 2013). The recognition of the material world as an element of the cognitive process exalts the active role of the materiality of objects in studies of the human mind.

Expanding on the concept of the theory of embodied mind (Varela et al., 1991), the materials composing the environment surrounding us, including objects within it, have a direct effect on our cognitive processes. The materials composing an object are shaping the object's materiality, its physical characteristics and properties. Consequently, the variety of affordances materials offer shape our interaction with the surrounding environment by modifying the sensory experiences. By following this line of thought, once the experiences of our bodies are transformed by altering the physicality of our surroundings, our perception, thinking and understanding change.

One of the study lines of cartography is cognitive cartography. Following the empiricist paradigm of cartography, cognitive cartography aims to study the effect of design variables on the map on the spatial knowledge and perception of the map users (Caquard, 2015; Żyszkowska, 2015). However, cognitive cartography has not been limited to map cognition and understanding, but also as an approach that can study the effect of cartographic variables in emotional responses (Griffin & Mcquoid, 2012). Following the acknowledgement of the importance of materiality in the cognitive processes, materiality as a variable represents an opportunity of expanding the lens of in cognitive cartography.

The concept of embodied mind has been recognized by cartographers as a basis for cognitive cartography studies. In the published study "Emotional response to map design aesthetics", (Fabrikant et al., 2012) explores the concept of the embodied mind by studying the effect of map design elements, in this case color, on the emotional response of users and the trustworthiness and likeability of a variety of maps with different color palettes. Considering this cognitive cartographic approach that recognises design variables as influential in map perception and response, it is valid to wonder about the effect of other elements like material selection on those interactions as materiality is already a mentioned topic in cognitive science studies.

2.3 Materiality as a Communication Tool in Arts

The interest in understanding materiality and using it as a tool is a prevalent theme across various disciplines. In the field of visual arts and art history, materiality has evolved from being a subordinate element to emerging as a dynamic agent that contributes significantly to the meaning of the artwork (Lange-Berndt, 2015). Materiality is currently conceived in these fields as "how art's material qualities are sensed, interpreted and understood" (Murdoch Mills, 2009, p. 2). In the collection of essays "Materiality, (Documents of Contemporary Art)", Lange-Berndt emphasizes the importance of acknowledging materials, suggesting that overlooking them perpetuates a long-standing tradition of prioritizing one aspect of dualities, mind over body, form over matter, design over material (Lange-Berndt, 2015). According, to (Hölling et al., 2019) this process of privileging has its origin in Western philosophy with the prioritization of the conceptual over the matter derived from Plato in his Doctrine of Ideas, and later on the superiority of form over matter proposed by Aristotle. The author further notes that as visual arts separated from craftsmanship, the material often took a backseat in the creative process, relegated to the role of a mere medium in service of representation. However, with the rise of the material turn in the social sciences and the exploration of material

agency (Bennett, 2010), the art world too has shifted its traditional perspective on the role of materials. Now in the realm of arts, materials are regarded as “complex entities with the power to convey meaning and to signify themselves” (Hölling et al., 2019).

Following the mentioned ideas, communication then extends beyond the form causing a deliberate selection of materials by artists based not only on practical considerations of technique and form, but also on the social connotations, symbolism, and sensory qualities materials bring to a composition. Furthermore materiality is one of the variables shaping the embodied experience of users. Acknowledging this connection adds a new dimension to the perception and interpretation of artworks, offering new meanings by making use of the interwoven relation between form and material, see (Skovbjerg Paldam, 2013). Some examples of this exploration of materials as part of materiality of the artworks can be seen in the work of the following artist, where the role of materials composing the artwork play a primary role in their content.

- Magdalena Abakanowicz
- Louise Bourgeois
- Do Ho Suh
- Ai Weiwei (Straight, 2008-2012)
- Theaster Gates (Civil Tapestry 4, 2011)
- Ursula Von Rydingsvard
- Kristof Kintera (Postnaturalia, 2016-2017)
- Anselm Kiefer (The High Priestess/Zweistromland, 1985-1989)
- Marc Quinn (Self, 1991)
- Doris Salcedo (A flor de piel, 2013; Fragmentos, 2017)

Expanding in the use of materiality by one of the mentioned artist, Salcedo has explored through her art the absence caused by the victims of war and the materiality of her pieces is often a fundamental element of their meaning. The artist articulates this approach, noting, “each time I need to make a radically different piece to honor the singularity of each and every victim’s experience. So different that I need to go from animal fiber to stainless steel, from extremely heavy to immaterial”. Furthermore, (Enriquez, 2016), the curator of one of her exhibitions at Harvard’s Museum shares regarding Salcedo’s work, “she has found ways to arrest the natural aging process of organic substances such as grass, silk, and rose petals, conceiving works that blur the line between the permanent and the ephemeral, between sculpture and performance. She creates a materiality that is a fragile yet fierce act of mourning”. Salcedo’s artwork “A flor de piel”, Figure 2.1, consists of a blanket composed of thousands of rose petals carefully sewn together. The work is a tribute to the women victims of the conflict and through the use of materials it transmits fragility and at the same time, because they are flowers, it can be interpreted as a tribute. At the same time the physical characteristics such as the color of the petals resemble wounded skin (Museo de Memoria, 2012).

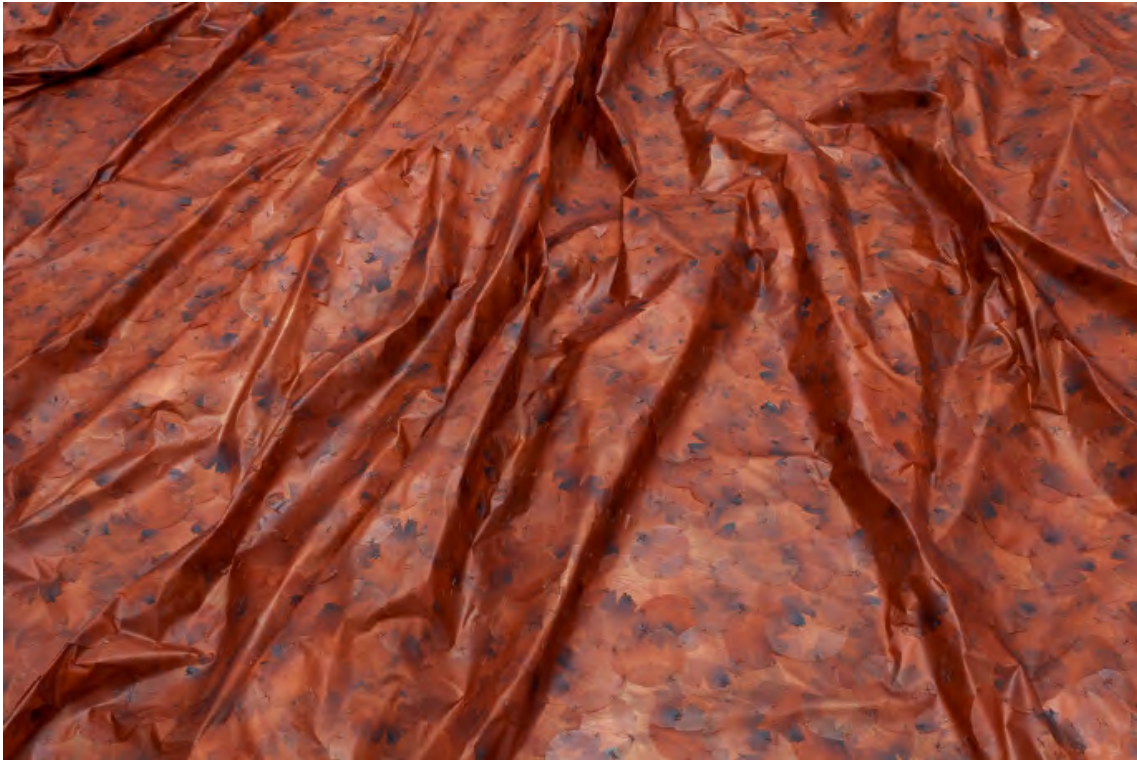


FIGURE 2.1: A flor de piel, Salcedo, 2013. Photograph: Lohse (Museums, 2023)

Insights presented by (Hong, 2003) provide further understanding when discussing materials and materiality in art. Through an analysis of the development of the understanding and use of the terms materials and materiality in art history, Hong's definitions of material, grounded in the Oxford English Dictionary, emphasize that material encapsulates not just the physical but also the potential of non-physical dimensions. According to the art historian, the significance of materials in art became popular after Hegel's understanding of the concept of *materie* as an element of physicality that was opposed to substance. This differentiation led to a split between the content and matter further explored later on by Marx. Hong presents this change of thought as the one taking materials to a prime role in art. Furthermore, the author notes that the emergence of the concept of materiality in art comes after Heidegger redefined the term "thing" to encompass more than just physical objects extending this abstractness to the concept of material. Building upon this materiality then became understood as "that which constitutes the 'matter' of something: opposed to formality; the quality of being material; material aspect or character; mere outwardness or externality" (Dictionary, 2001). Hong's sharings then cover the course of materiality in the 20th century, when discussions revolved around Greenberg's claim that the distinctiveness of art lay in its medium, which contrasted with Fried's stress on form instead of material. The author additionally states that such debates not only delineated the role of materials but also revolutionized the very definition of art and its relation to materials. Beyond the terminology used through art history to describe the physicality and components of art, materials and materiality are often used interchangeable in the realm of visual arts.

As it has been established, the possibilities of materials go beyond the practical approach of technicality, and involve also considerations of sensory experience and meaning in the context of the artwork. This is why there is an interest between artists to explore direct roles of materials in artistic endeavors. In a practice-led research, textile artist and researcher Nithikul Nimkulrat introduces the concept of materialness. The artist follows the previously mentioned idea of embodied mind (Lakoff & Johnson, 1999; Varela et al., 1991) to describe how artists think through action, in the case of craft through sensory interaction with materials. Furthermore, for (Nimkulrat, 2012), materials are not only relevant to the creative process, but also influence the subsequent viewing and interpretation of the artefacts. “A tangible material can participate actively in deriving the form, content, context and time of a craft artwork. Through these elements, the concept of materialness enables craft artists to convey an intended meaning to other people” (Nimkulrat, 2012, p. 2). Moreover, the artist illustrates the agency of materials in meaning with one of her artworks, *The Coffee Cup*, where she created a piece in the form of this functional artefact, but by using paper string as a material its functionality was altered. For Nimkulrat, *The Coffee Cup* then acted as a symbol, an aesthetic artefact that made the viewer question the routinary perspective of the role of the thing. The representation questioned the relationship between appearance and functionality, and stressed the importance of cups. The material then controlled the form and in her words “the Coffee Cup lost the function of a cup but gained new meaning given by the maker, which was perceived, identified and understood by the viewers” (Nimkulrat, 2012). This is just one of many examples in art where a change in material leads to changes in the perception and meaning of artworks and artefacts.



FIGURE 2.2: *The Coffee Cup*, Nimkulrat 2009.

In pursuit of understanding and exploring the potential roles of materials in the creative process, several artists and product designers have embraced a perspective that considers creation as an action guided not only by preconceived ideas but also by the exploration and sensory interaction of materials (Aktaş, 2018; Nimkulrat, 2010). Under this scope, the agency of the materials is studied from the perspective of materials being co-designers (Aktaş, 2018). This approach allows the understanding of the physical affordances of materials during sensory interaction that “can

ultimately create a smoother and richer process of creative production” (Aktaş, 2018, p. 14), where the design considers the natural characteristics of the materials. For further insights on the interaction between artists and material refer to (Lange-Berndt, 2015).

2.4 Materiality as an Element of Affordance in Design

By modifying the physicality of objects it is possible to shape the behavior of people in their interaction with the objects. Changes in design, form and materials lead to new affordances that an object has to offer (Gibson, 1966; Stienstra & Bruns Alonso, 2012). The relation between the physical properties of objects and the resulting behavioral changes in individuals is of particular interest in the field of product design.

Trough the study of how materiality shapes and influences emotional and behavioral responses and interactions between user and object, designers can conceptualize objects that effectively guide users towards the aimed result on their encounters. An essential aspect of modifying materiality is the selection of materials. Furthermore materials become a direct influence in human perception, behavior and emotional responses in user-product encounters (van Kesteren, 2010).

(D. Norman, 2003) introduces different levels of design: Visceral, Behavioral and Reflective. At the Visceral level Norman explores how humans elicit emotional responses to physical characteristics like colors and sounds. Norman exemplifies this phenomenon by presenting how following evolutionary reasons, like primates being attracted to colorful fruits, resulted in humans feel drawn to vibrant colors like the colors of the fruits. Moving on to the reflective level, Norman explains it as the conscious reflection about the product. This level can be influenced by the materials that compose an object. The social meaning of materials can impact users’ perceptions of an object. An example of this is the opinion a person would have of a product that uses sustainable materials. Such a product is likely to be perceived as morally right or environmentally conscious due to its material choices. Senses then play a fundamental role in human perception and response to objects. Sensory experiences serve as a first step in human-object encounters, leading to a first impression of what is being perceived. Subsequently, the reflective level connects the sensed information and our social constructions enriching our understanding of objects.

The interest of understanding materials as a variable of design and its effect on users, has motivated different studies in the realm of design. (Karana, 2009) in her PhD thesis “Meanings of materials” studies the way materials obtain their meanings and how, through the interaction with other variables of product design, they are able to communicate meaning. Karana, after conducting several studies involving user perception of raw materials and products manufactured with those materials recognizes in the users’ descriptors of the material experience several roles of the material selection in product design. On one hand the practical choices behind the selection of materials are based on their affordances, like using glass for seeing trough or wood and metal for structural support. Furthermore, materials can be chosen due to the pleasant sensorial experience it can bring to users, like the softness of wood for example (Karana, 2009). In addition, materials can evoke emotion

of product users and be recognized as having a meaning. These two last aspects are dependent not only on the material itself, but also on the context it is presented as a part of an object and on the personal experience (Crippa et al., 2012; Karana, 2009). All these variables become essential considerations in the material selection process in product design.

2.5 Discussions about materiality in Cartography

The approach to materials by cartographers has mostly had practical motivations. The materials used in maps have evolved with civilizations. Materials as stone, bone, leather, textiles and paper have been used in map making throughout history (Rossetto, 2019). Nowadays map's most common media are paper and digital media possibly resulting on the affordances of both media and their facility for tasks as navigation. Digital maps can be easily accessed in a wide range of spatial and temporal contexts, same for paper that represents a material that is easy to carry in a society as dynamic as ours.

The use of various materials by cartographers with a communicative intention behind the material is not frequently encountered and not extensively documented. Nevertheless in the field of arts, the experimentation of artists with maps and their exploration of cartographic elements has developed in recent years. In the book *Map as Art* (Harmon, 2009) presents a recompilation of artworks of artists experimenting with cartography. Some of the artists broke the most classical representation of maps and created maps using different materials. In a review of the book, social geographer Robin Flowerdew highlights the material selection in some of the artworks as a means to convey a message through the subversion of the norms of conventional cartography. This situation is exemplified by the artwork "A walk in L.A" by the artist Carl Cheng. Cheng created a large-scale stone roller that served as a giant mold. When dragged by a tractor the cilindric mold left a map of Los Angeles marked on the sand of Santa Monica Beach. From a cartographic perspective, this artwork raises various considerations in the way that material selection transforms different cartographic variables. One could question the meaning of the impermanence of the map on the sand, as well as the map's replicability, the affordances and interactions it allows for people and the scale.



FIGURE 2.3: Charles Cheng, 1988, Walk on LA.

Another of the multiple artworks presented in *Maps as Art* is Qin Ga's *The Miniature Long March* 2002-2005. The artist traced and continuously updated a map tattooed on his back following China's Long March Project on their 6000-mile Long March following a historic route. Later Qin Ga personally continued the route accompanied by a tattoo artist and a camera person. In this artwork the artist becomes an integral part of the materiality of the map prompting questions regarding the motivation and personal and perhaps emotional connection with the map and its theme. This is one of the examples where the impression the artwork causes and the perception the public has of it is influenced by the physicality of the map and the context around it. The afore mentioned are just a couple of cases that exemplify the acknowledge of materiality of maps and the possibilities of expanding the use of materials in the realm of cartography, from selecting materials merely by practical reasons and considering further significance of materials in map making. The integration of material studies to cartography can be approached through different perspectives already developed in the cartographic field.

Critical cartographers challenge the traditional notion of maps as objective representations of reality by highlighting their role as an expression of power and knowledge, and their susceptibility to the influence of social and personal contexts, often laden with ideologies (Bunge, 1971; Harley, 1980; Wood, 1992). This perspective draws a parallel between maps and artworks, recognizing them both as vehicles of representation and communication of ideas (Morrison, 2011). Notably, there exist shared attributes between visual art works and maps (Cosgrove, 2005), as both forms can encompass visual and material dimensions. Materiality as it has been explored in the realm of arts, can become dimension of cartographic interest when acknowledging materials as active carriers of meaning.

Another ongoing discussion in cartography is the comprehension of the main object of study in the field, the map, as processual rather than solely a completed object. The vision of processual cartography proposes to understand maps beyond the finished product, but as a fraction of a wider

phenomenon where the map should be studied in all its stages, from creation, production and user interaction. Therefore mapping can be approached as a chain of elements where there are physical elements that allow embodied interactions occurring in a context. It is the combination of all these components, that offers a more holistic study of the maps according to the processual scope of cartography. After following the ideas mentioned in the previous sections, where different fields recognize the perspectives that materiality offers to each study, it is interesting how it becomes possible to perceive the concepts mentioned in all those fields intertwined with new approaches of cartographic studies. (Ingold, 2007) talks about understanding materials and their perception as processual, where the environment has an active role on how materials are perceived. Furthermore in the cognitive sciences, (Malafouris, 2013) presents the material engagement theory where human cognition is understood from an embodied experience of the mind and therefore the materials composing the environment play an active role in human thinking as they shape the cognitive process. Both approaches feel familiar to the processual scope of cartography, leading materiality to a space where it can be considered in cartographic studies as shaper of the experience between cartographer, map and user.

Continuing in this context, another important conversation within cartography is the consideration of the field and its central subject, maps, as processes rather than static objects. Processual cartography advocates for a thorough comprehension of maps that goes beyond their end result, viewing them as essential elements of a larger process that includes creation, production, and user engagement (Caquard, 2015; Dora, 2009). This approach situates mapping as a set of interlinked components, taking into account physical exchanges within particular contexts. The blending of these parts offers a thorough perspective for studying maps, in line with the guiding principles of processual cartography. After exploring the concepts discussed earlier, that highlight the perspectives that materiality offers across disciplines, it becomes a matter of interest to explore how these notions can intersect with emerging cartographic paradigms. (Ingold, 2007) introduces the idea of understanding materials and their perception as processual, emphasizing the environment's active role in shaping material comprehension. Similarly, within the cognitive sciences, (Malafouris, 2019) presents the material engagement theory where human cognition is understood from an embodied experience of the mind and therefore, the materials composing the environment play an active role in human thinking as they shape the cognitive process. These frameworks resonate with the processual scope of cartography, positioning materiality as an influential factor in cartographic studies. This framing invites the exploration of materiality as a potential agent that shapes the dynamics between cartographers, maps, and users, broadening the epistemological approach of cartography.

Some authors in the cartographic field are already sharing their considerations regarding the role of materiality and materials in maps and their study. (Edney, 2019, p. 34) states “the study of the variable material nature of maps - including their immateriality- is a crucial component of a processual approach to mapping and map history”. Moreover, (Dora, 2009, p. 240), following again ideas related to processual cartography, proposes the “re-conceptualization of maps as fluid objects that are always in the making” and interpreting as fundamental the interactions between map makers and map users. (Dora, 2009) also shares the perception shared by (Jacob, 2006, p. 6-8), who directly

states that “the history of cartography can no longer be envisaged without attention to the materials of which maps themselves are made”. The recognition of materiality as it has been explored in the context in diverse fields, now reaches cartography and it becomes evident in statements like “Materiality is important, because the effects of a map largely result from its materiality and from the specific pragmatics of its viewer’s body and gaze” (Dora, 2009, p. 244). The aforementioned are some of the recent discussions the cartographic world has experienced. After the recognition of the material compositions of maps other discussion strongly connected to the principles of cognitive sciences have emerged, as tactile mapping.

Scholars like (Olmedo, 2018) have manifested the aim of returning sensitivity to cartography. The author, through a textile map project explores the alternative manifestations of mapping by questioning the hierarchy of the senses by challenging the visual primacy and emphasizing the importance of the haptic dimension of maps. Through her project the cartographer touches concepts of embodiment and cognitive cartography while also performing an exercise of collaborative cartography with a community of women in Marrakech. Olmedo also builds her arguments from the perspective of processual cartography showing a special interest in the use of the map as a part of the interactions occurring as part of the cartographic process.



FIGURE 2.4: Olmedo, Textile Maps of Moroccan Working-Class Neighbourhood in Marrakech

In addition to the visual aspect, the tactile dimension of maps is now receiving increased attention (Rossetto, 2019). Beyond traditional crafting processes, technological advancements in machinery, such as routers, vacuum formers, and laser cutters, along with the exploration of new materials, expand the possibilities for creating maps in diverse materials. These advancements also provide alternatives for precision in manufacturing and replicability, paving the way for physical maps that incorporate digital techniques while exploring new media. According to (Kent, 2019, p. 2), tactile

cartography offers a notable scope of research in cartography and “it is worth setting a broader aim for tactile mapping, i.e. one that goes beyond providing a substitute for the visual experience by fully exploring the aesthetic and cognitive possibilities that tactile media offer cartography”. Nevertheless, the impulses for diversifying the sensory experience in map-user encounters, do not end on the haptic affordances of tactile maps. Cartographers and artists have further explored alternative multisensory maps.

(McLean, 2020) has focused her work on exploring multisensory experiences through her maps. At the same time she depicts sensory related data. The cartographer developed for example maps based on sensory perception like Smell maps of different cities. In this project, McLean, after data collection of the smells perceived in cities, not only visualizes the data in a traditional visual format, but also proposes parallel maps that involve the smells, expanding the sensory experience of the map. This project is an interesting exploration of materiality through a deep connection with the topic being mapped. The sensorial experience given by the smells in the map aligns directly with the data collected from the same sensory exploration of the city. Furthermore the project offers new ways of recognizing platial characteristics beyond the visual and sets the scenario for an multisensorial embodied experience on the map-user encounter. These sensory affordances also lead to processes involving memory and emotion of the users. McLean’s findings, when presenting the Smell map of Paris, support this idea. She states, “coffee smells incite people tell a story, a whiff of perfume encourages people to mention other people, wine is most likely to make people recall an event they attended. Locations might be very specific (Grandma’s front room) or general (it’s a railway station)”. Moreover interesting insights come from this type of cartographic approaches that connect ever existing human body capacities trough a change on the material existence of maps and the type of actions they allow.



FIGURE 2.5: McLean, Smell map: Paris

Following the presented approaches of cartographic studies to the materiality of maps, it is possible to see that there is a growing interest on understanding maps through a materialistic approach. When

building upon concepts emerged in other study fields like social sciences, cognitive sciences, design and art, cartographers have been exploring the possibilities of acknowledging the materiality of maps, and finding potential in the conscious integration of material selection in the cartographic process. This vision allows to consider the effect of the physical existence of maps and their affordances provided by their materials, on the embodied experience cartographers and users share with maps. Further interest has risen in the exploration of multi sensory maps that can offer a whole new experience to the users and might change the supremacy of the visual elements of cartography, widening the field of cognitive cartography. However, there is still a gap in understanding the role of material selection for map making in the cartographic process, from the cartographer's creative process to map production and the subsequent encounter between map and user. The aim of this project is to explore this gap through the implementation of a case study.

2.6 Literature Review Output

The aim of the literature review was to gain a comprehensive understanding of the concept of materiality and its role across various disciplines. The Research Objectives 1 and 2 were addressed during this stage.

- **RQ1.1** How is materiality defined and understood in different fields?

The concept of materiality was reviewed under the scope of 4 fields, each of which has recognized its significance within the realm of their studies. In the context of social sciences, materiality can be understood as the agency of objects through their physical characteristics to shape human behavior (Lievrouw, 2014). Materiality then is related to the physicality under the lens of social interaction, how humans interact with objects, and how the physical properties of these objects can guide the human experience and behavior. In the case of media studies as part of social sciences, materiality is also understood as the influence types of media and their physical attributes have over societies and cultures. In the realm of cognitive sciences, materiality once again is understood as the physical attributes of material forms (Overmann & Wynn, 2019). Materiality is of interest to cognitive sciences because the effect of the interaction with these physical forms shapes the cognitive processes and the way humans think.

On the other hand, in a more practical approach in the fields of visual arts and design, materiality is also understood as the physical expression of whether an artwork or a product and how these material properties are sensed, interpreted, and understood (Murdoch Mills, 2009). Nevertheless, materiality can have more abstract forms, as artworks can encompass diverse expressions such as performances and diverse physical forms such as sounds or human interactions. This physical manifestation can also compose the materiality of a piece. However, in certain scenarios, materiality can refer to more traditional components of the artwork or object, being then the materials the ones that compose the materiality of a piece. In

these fields materiality is also understood through the significance of the material expression in the context of the artwork or the object, materiality is closely linked to the intention of the creator (artist, artisan, designer) and the interaction between viewer or user and the piece.

- **RQ2.1** How is materiality relevant, and why has it been studied recently?

In social sciences, the material turn, a moment that changed the paradigm of social sciences in the twentieth century, started giving importance to the materiality of cultural artifacts. Scholars began to find in the physical world information about more abstract subjects of study as human relations, behavior, and cultural expressions. From the study of the physical manifestations of civilizations, discoveries about their social practices could be derived. Furthermore, fields like design find in materiality a tool that allows the designer to shape the behavior of the user in the interaction with the product. Through the sensory experiences that materials composing objects lead to, the user experience varies, users have a sensorial perception that can derive from various behavioral responses, emotional responses, and opinions about the object that is being perceived. In the realm of visual arts, materiality has also been recognized as a study of interest, information about artwork, the artist and the techniques can be derived through the study of its physical composition. Additionally, artists envision the materiality of their pieces by considering how the materials can generate an effect on the viewers or how the use of certain materials can carry significance due to the symbology behind their use.

- **RQ2.2** How is materiality understood as a carrier of meaning?

Materiality can convey meaning in various ways depending on the specific context. When discussing the materials used in a physical element, they may carry significance in the historical, geographical, and societal contexts. Furthermore, the choice of materials can intentionally transmit meaning due to their origin, physical properties, or symbology.

For instance, in anthropology and archeology, material culture can provide information about culture, social status, gender, and human relationships (Hirst, 2021). Although material culture focuses the meaning of objects to humans, the analysis of materials in the objects also carry meaning. Discovering an object from a civilization that uses materials not naturally found in their area may prompt speculation about potential connections with other civilizations that had access to those materials, leading to possible insights on cultural interactions or trade networks. Additionally, the analysis of an object's materials may provide insight into its owner's socioeconomic status based on value or cultural usage restrictions.

In the context of product design, according to (Karana, 2009) argued in his doctoral thesis, titled "Meanings of Materials", that the physical characteristics of materials are often used to transmit meaning and values to products. Materials can be for example perceived as elegant, cozy and futuristic. However, the interpretation of the material is deeply connected to the context or product in which it is presented and the personal background of the user.

In visual arts and design, material composition plays a crucial role. In various artworks,

materiality acts as a carrier of significance, instead of just a medium for allowing a shape. Examples of this case were discussed in Section 2.3 where the material of the artwork give valuable insights for its interpretation possibilities. In such cases, the artist intentionally uses the meanings attributed to the materials to evoke emotions, and sensory experiences and engage the audience in reflection. Therefore, the role of materiality as a carrier of meaning can be perceived under different scopes, including historical origins, social implications, and even intentional artistic narratives.

- **RQ2.3** How has materiality been understood as an active element of communication?

Materiality can play an active role in communication through the physical properties of materials and their affordances. These properties affect human interaction and perception, thus conveying messages to people. The sensory experience humans have of material qualities plays a role in the cognitive processes resulting from human-object encounters. Sensory experiences are often considered in creative processes and design in the fields of art and design, where materials are consciously chosen to elicit specific responses. Additionally, the affordances of materials, as part of the physical expression of objects, influence behavioral responses in human-object interaction. Materiality through material selection is, therefore, a design variable that conveys a specific purpose. Materials can also communicate through their symbolic load, where individual and social interpretation play a primordial role. Furthermore, materiality can be seen under a processual lens where the human interaction with the physical properties, the context, and the environment are active agents on the significance of the material.

Chapter 3

Conceptual Overview

This chapter presents and describes the general research approach followed during the study, the research methodologies, and the research methods adopted in order to answer the research questions set out in Section 1.2. Furthermore, the epistemological approach of the project is presented and described for each stage of the project. The way the generation of knowledge is established throughout the projects and the adopted paradigms are presented and described.

3.1 Methodological Approach

In search of exploring the relevance of the acknowledgment of materiality in cartography, a mixed method approach was pursued. The mixed method approach combines qualitative and quantitative research methodologies, allowing a better understanding of the studied topic, giving richer insights, and allowing the identification of causal relationships (Jefferson, 2014). Additionally, the mixed method approach is considered convenient to be applied in social and behavioral research as an element that gives multiple perspectives to a “reality that is both plural and unknown” (Maxcy, 2003). The research project was developed in three stages that involved different research methods. The general framework of the study is presented in 3.1

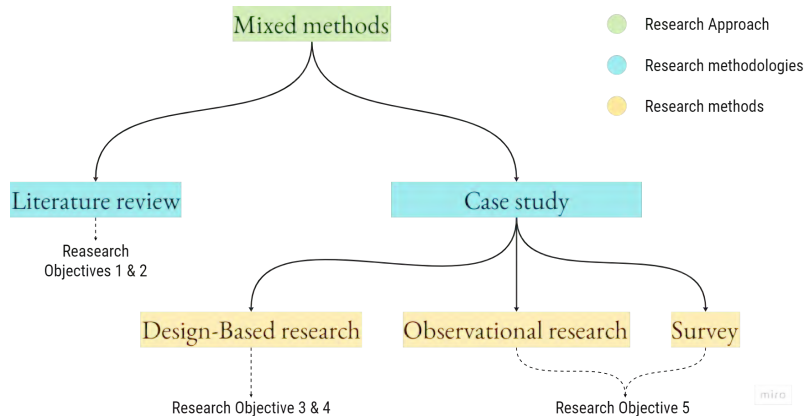


FIGURE 3.1: Research Approach.

The first stage was composed of a literature review that led to an understanding of the concept of materiality and why it is a variable of interest in different study fields. Materiality was acknowledged to play active roles in processes studied or developed in the aforementioned fields, such as cognitive processes (Malafouris, 2013), communication (H. A. Innis, 1951; Malafouris, 2013), creative process (Aktaş, 2018; Lange-Berndt, 2015; Nimkulrat, 2012). The literature review led to an interest in the exploration of the possibilities of materiality as a cartographic tool, after recognizing maps as elements that involve users in cognitive processes and understanding materiality as an active element of cognition (Malafouris, 2019; Perkins et al., 2011). Maps also seek to communicate messages, represent places, and are profoundly connected to cultural elements (Morrison, 2011; Perkins et al., 2011). Linking cartography to other fields, by finding common interests of study, and subsequently understanding the interconnections of those elements to materiality justify the exploration of material selection in maps as a matter of interest and an opportunity to generate new knowledge in cartographic studies. Once the motivation for the research was defined, a study was designed and conducted, to get an insight on the potential role of materiality in different stages of the mapping process.

For the second stage, a case study was defined by selecting a topic to be mapped Section 3.2.1. After this defining stage, a conventional map in terms of materiality was also selected. The map, was printed on paper and from now on is referred to as “paper map”. The paper map was used as a base in terms of its data to produce a map composed of different materials from now on called “material map”. A design-based research methodology was followed during this stage. The creative process of the material map allowed an exploration of the possibilities of incorporating materiality as a design variable and the alternatives of the use of different materials in the map production process. This stage of the project used methods of artistic experimentation and cartographic design. The third and fourth research objectives in Section 1.2 and the related research questions were accounted for in this stage of the study. Once this stage was finished the user study stage began.

After the paper map was selected and the material map was produced, a comparative user study was designed to gain insight into the interaction and perception of users of the maps. The study consisted of presenting the two maps to participants, both maps shared the same topic and represented the same data. The maps differed in aspects marked by the design but mainly by their materiality and therefore by the allowances of their media. Both maps characteristics are widely presented in Section 4.3 and Section 4.4. During the interactions map-user an observation research method Section 5.2 was conducted by the researcher and a questionnaire Section 5.3 was answered by the participants. The implementation of both methods offered the quantitative and qualitative data that after its analysis would offer the starting point to achieve Research Objective 5 Section 1.2.

3.2 Epistemological Approach

The epistemological approach of this project delves into different paradigms to derive knowledge based on the frameworks followed in each section. Various lenses of different fields of study were employed, resulting in a range of methods applied throughout the research process. The project comprises three main stages, each aligns with a corresponding paradigm. Therefore, the research adheres to the pragmatic paradigm for producing knowledge by employing diverse available approaches (Savin-Baden & Howell Major, 2013).

The initial step of this research involves conducting a literature review that is based on both positivist and interpretivist paradigms. The positivist paradigm enables the researcher to synthesize and analyze the theoretical background and previous studies of materiality research. This offers a clear description of the current state of knowledge for the present study. Furthermore, the interpretivist paradigm, which recognizes the contextual load and the role of the researcher and their subjective nature (Dawadi et al., 2021) offers the recognition of the dependencies of knowledge on individual interpretation and social constructs. By adopting both paradigms, this section examines existing knowledge about materiality from various fields to establish a foundational understanding and contextualization of the concepts addressed in the study. Also, it presents various approaches pertaining to the overarching theme that will establish the basis for subsequent evaluations of the results obtained through the project.

The case study, as the second stage of the project, follows a practice-led research approach, commonly applied in art research. This approach recognizes the role of the maker in terms of their personal experience and reflection, which serves as a the base data to be examined by the researcher, who may also be the same person, following the practitioner-researcher model (Mäkelä, 2016; Williams, 2001). For this section, a combination of positivist and interpretivist paradigms is also followed. This stage involves a creative process and an exploration of the possibilities of material significance and interpretation that recognizes social and individual experience and context, typical of the interpretivist approach. The narrative development of this section follows the personal perspective of the maker that also analyses the experience from the role of the researcher. Simultaneously, the case study adopts a structured methodology that incorporates positivist principles by working with scientific data and adhering to design principles and empirical observations.

For the final stage, the user study is designed following more classical research methods that allow quantitative and qualitative data collection, therefore aligning with a pragmatic paradigm overall. With the aim of capturing participants' subjective experiences methods, aligned with an interpretivist paradigm, commonly followed in social sciences research are employed. The observation and open-ended questions compose this approach. Nonetheless, the study also collects quantitative data and analyze it using statistical methods to derive possible patterns on the responses. This methodological approach is traditionally followed by a scientific research paradigm, and aligns with a post-positivist paradigm. The post-positivist paradigm pursues objective answers but recognizes the individuality of the researcher influences the way the data is approached and the conclusions (Cooper, 1997). In addition, the post-positivist paradigm "allows more interaction between the researcher and his/her

research participants” (Taylor & Medina, 2013, p. 3), fundamental in the set-up of the user study. Additionally, the literature review provides a basis for knowledge creation through data interpretation that follows the ideas and existing knowledge of the previously explored fields.

Chapter 4

Case Study

This chapter introduces the case study selected for both maps in the user study. Various conventional media maps are then discussed. The chosen conventional media map is presented. A detailed description of the creative process and production of the material map is presented, emphasising in the material selection process. The materiality exploration of the map is discussed, including the consideration of different materials, analysis of their physical characteristics, possible affordances, meaning in relation to the topic of the map and the possibilities of the map design. To conclude, the process of elaboration of the material map is presented and accompanied by the narration of the experience of the mapping process from the perspective of the map maker.

4.1 Topic Selection for the Case Study

A relevant topic in cartography nowadays is the representation of environmental topics (Svenningsen, 2016). Deforestation and forest degradation are some of the environmental challenges the planet is facing. Human demand for resources and land is threatening the existence of various ecosystems, causing changes in natural cycles and challenging the future survival of numerous species, including humans. The largest remaining tropical forest is the Amazon biome, located in the Amazon region of South America. Its existence is vital to the world's biodiversity and plays a fundamental role in environmental issues. During the last decades, different organizations like RAISG, and governmental agencies (INPE) have collected data on the changes in the Amazonian ecosystems. Maps including topics like land use and deforestation have resulted from this process. The human impact on the Amazon region and the deforestation in its biomes has been chosen as the study case of this project as it is a topic of current relevance and from an environmental and social perspective its divulgation in society is fundamental as the problem is directly related to human consumption and product demand (Lapola, 2011). Maps serve as an effective communication tool to illustrate the current scenario of this issue in society. The degradation of the Amazonian region was selected as the topic for the case study of the project also as an opportunity to explore new tools of communication in a topic that requires to be taken into consideration.

The Amazon region is commonly defined as the combination of the Amazon biome that holds the tropical jungle with around 7 million km² overlapped with the basin of the Amazon River with 6.9 million km² (RAISG, 2020). The Amazon biome, shared by the South American countries of Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, and French Guiana, is the biggest remaining tropical jungle. The Amazon has an impact on global cycles like the carbon cycle and the water cycle and it influences the climate of the whole planet. Moreover, the Amazon jungle is home to at least 10% of the known species of the planet, being one of the most vital ecosystems worldwide. Therefore the preservation of the Amazon region is the focus of environmental efforts, however, changes in the land cover are currently putting pressure on the region leading the ecosystems to a point of no return (Lovejoy & Nobre, 2018; Quintanilla, Guzmán, & Josse, 2022). This stage is reached when a permanent change in the ecosystem is projected once the forest is permanently unable to recover.

Deforestation of the Amazon has been guided by consumerism in modern times. Around the 60's Brazil's Military government's expansive ideology of "integrar para não entregar" (integrate not to give) built roads through the jungle opening the way for illegal deforestation (Bittencourt das Neves et al., 2021). From 2001 to 2020 the Amazon jungle lost 542,581 km² of forest (RAISG, 2022), reaching a risk point for the possibility of regeneration of the ecosystem. The recent political situation of Brazil summed to the lack of surveillance due to the COVID-19 pandemic led to an acceleration in the deforestation of the Amazon (Pereira & Gebara, 2023). The attitude and narrative towards the management of the forest impulsed by the ex-president Jair Bolsonaro gave more freedom to illegal deforestation (Pereira & Gebara, 2023) during Bolsonaro's ruling years from 2019 to 2022 the Brazilian Amazon lost 45,586 km² (WWF Brazil, 2022). It is a current discussion within the scientific community when would the tipping point of the Amazon occur, at which percentage of forest degradation (Vergara et al., 2022) and how could the current panorama be reversed aiming to avoid the already occurring savanization of the forest (Quintanilla, Guzmán, & Josse, 2022). Although there is a change expectation caused by the proposed policies regarding the forest's protection by the new government, a reverse in the degradation of the Amazonian ecosystems is needed to avoid a future point of no return (Vergara et al., 2022).

During the research stage of the deforestation of the Amazon jungle, several aspects related to the issue became elements of interest that were chosen to be portrayed on the proposal of the material map. First, a special interest in understanding the drivers of deforestation seemed fairly natural. The Amazon jungle is not only seen by our society as the home of a high amount of species and a fundamental climate regulator. If this were the dominant perception in the region, problems such as deforestation would not be so severe as to pose an imminent threat to the health of Amazonian ecosystems. The vision that society has maintained for decades of the Amazon is that of a source of resources, not only environmental resources such as the water that produces or the carbon that it captures, but also non-renewable resources such as soil, timber, and minerals that are exploited daily under economic interests (Picoli et al., 2020; Quintanilla, Guzmán, & Josse, 2022). On the discussion of the material and symbolic meanings of the Amazon forest (Pereira & Gebara, 2023, p. 327) describe the dominant perception of the forest as "one of an exploitable commodity source

... fed by the violent paradigm of global materialism and consumerism.” The economic interest behind the Amazonian region fueled by a consumerist society directly contributes to the drivers of the Amazon degradation. Nevertheless, some economic activities remain the most notorious culprits behind the degradation of the Amazonian ecosystem, such is the case of livestock farming and agriculture.

Livestock is the main driver of deforestation in the Amazon region. Livestock expansion requires large areas of land, leading to deforestation to make way for cattle pasture (Machovina et al., 2015; Margulis, 2004; Picoli et al., 2020). By 2008, it was estimated that cattle ranching was responsible for 80% of deforestation in the Amazon region (Nepstad et al., 2008). The economic interests of those involved in illegal deforestation to generate area for pastures are fueled by the international demand for meat consumption. Meat production not only leads to deforestation to create grazing land, but also indirectly contributes to it by causing the expansion of arable land through the demand for livestock feed. For example, soy production, which is mainly used as livestock feed, has been linked to deforestation in the Amazon and about 80% of soy production is destined for livestock feed (Flores et al., 2010). Thus, the growing demand for meat perpetuates the perception of the Amazon as an area to be exploited for human goods and economic benefits.

4.2 Conventional Deforestation Maps of the Amazon

Once the topic of the case study was defined, the process of selecting a conventional map in terms of its media started. Different digital maps to print on paper for the user study were considered. As a criteria for the selection, the complexity of the information presented was considered. The conventional map was chosen to work as one of the elements of a comparative study along with a map that was unconventional in its media but equivalent on its depicted data. To reduce the variables in the equivalent maps, a map with a relatively small amount of components was considered a better fit for the project. In the following section, different alternatives of maps about the degradation and deforestation of the Amazonia are presented. Additionally, the selection criteria are outlined, and the final choice is justified.

4.2.1 Amazonia the Human Impact

The first map considered was National Geographic’s portrait of the Amazon’s environmental situation. The map published as a supplement of the magazine in August 2018 presents the detailed panorama of the impact of humans on the amazonian region. The map production was conducted by Scott Burkhard, Lauren C. Tierney and it the edit was done by Gus Platis. As a general overview, the map is a multi thematic infographic including 4 thematic maps and an inset map all complemented by text. The impact of roads and the hydroelectric projects on the region are the depicted on the central map on a bigger scale. The main map is accompanied by 3 smaller maps, the top left map portrays resources of the Amazonian region including minerals and gas. On the other hand, the top

right map presents the managed areas of the region, offering the information regarding the protected natural areas, and the indigenous territories. Finally on the bottom left map the altered landscape of the Amazon is depicted by presenting data of the fires on the region and the level of deforestation.



FIGURE 4.1: AMAZONIA The Human Impact, (National Geographic Society, 2015)

The map was digitally produced and it was based on four different data sources by RAISG, the University of Maryland, Nasa, the USGS, James Cook University and Woods Hile Research Center. The Map contains classic cartographic elements such as a scale and legends. Additionally, it mentions the cartographic projection used, Azimuthal equidistant projection. The limit of the region depicted on the map is the limit proposed by the RAISG.

4.2.2 Amazon Landcover

Another map considered to be the conventional media map was a map produced by Lauren Dauphin and published by Nasa's Earth Observatory on the four part series Amazon Deforestation. The map presents the different landcover types, in and around the Amazonian region, using false colour satellite imagery (Dauphin, 2019). As the map uses satellite images, the accuracy of the geographic representation is rather high. The map contains classic cartographic elements as a north arrow, a scale and a legend. In comparison to the previous map of National Geographic, the information presented is considerably reduced as only one thematic is portrayed. However, the geographic information is detailed as the data is categorized in 6 types of landcover. The general layout of the map is indeed simpler than the previous consideration and the text annotations are minimal.



FIGURE 4.2: Amazon landcover (Dauphin, 2019)

NASA Earth Observatory's map was also digitally produced, the author used data from MODIS from the NASA and Landsat from the U.S Geological Survey, together with data from the University of Maryland, the Shuttle Radar Topography Mission (SRTM) and the World Wildlife Fund HydroSHEDS Project.

4.2.3 Amazonia Landcover and Landuse

As the third option, the map of land cover and land use by the Amazonian Network of Georeferenced Socio-Environmental Information (RAISG) was considered. RAISG is a civil consortium organization from the Amazonian countries producing knowledge and Data related to the social and environmental development of the Amazonia (RAISG, n.d.). Through the project Mapbiomas, RAISG publishes annual maps of landcover and landuse of the Amazonia. The data depicted in the map was obtained by the RAISG through the classification of Landsat data, resulting in 19

categories, including forest formations, agriculture, pastures, and mining. The layout of the map is composed by the main map of landcover, a legend to its right side of the 19 categories including also the information of the collaborators and the origin of the depicted data, to the upper left an inset map is provided, finally, summary table of areas of the categories and there corresponding percentages complements the map.

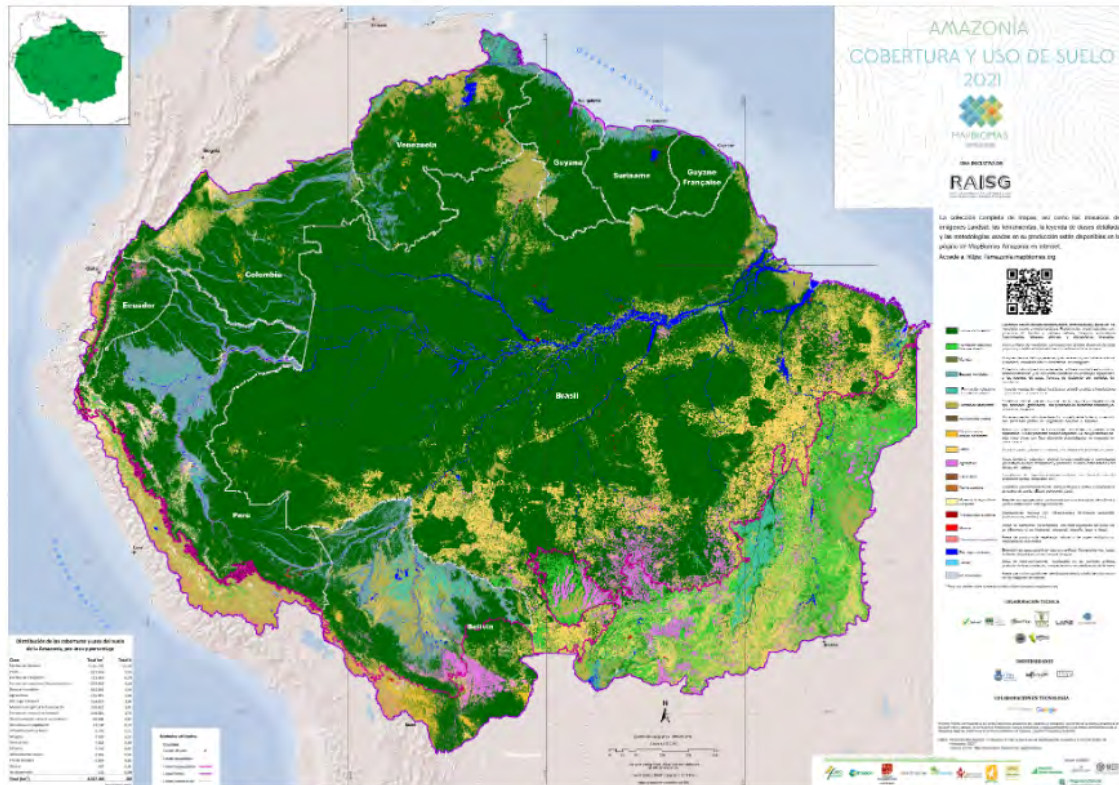


FIGURE 4.3: Amazonia landcover and landuse, (Mapbiomas, 2021)

For the maps RAISG applies classification algorithms to Landsat data to produce annual maps of landuse and landcover. According to the consortium the maps will be updated when improvements in classification algorithms are developed. Multiple sources of data were used for the map production, including the data of the world relief offered by ESRI. The map contains traditional cartographic elements like a north arrow, scale and coordinate grid. RAISG defines the limits of the Amazonian region by combining the limits of the Amazon biome with the limits of the Amazon Basin and the limits of the “legal Amazon” defined by Brazil. This limit definition, called RAISG limit is frequently recognized and used when mapping the Amazonia.

4.2.4 Amazonia: Key Priority Areas

The final option considered as a candidate for the conventional media map was selected from the report Amazonia Against the Clock, presented by the Coordinator of Indigenous Organizations of the Amazon Basin (COICA) and the RAISG in 2021 as a “global call to avoid the tipping point in the Amazon” (Quintanilla, Guzmán, & Josse, 2022, p. 2). The resulting publication presents a map

of the Amazon's regional outlook by 2020 regarding ecosystem degradation. Degradation is defined on the study as “as the sum of fires, carbon loss, and deforestation by intensity: no degradation or intact, low degradation, high degradation, and total transformation of the natural land cover” (Quintanilla, Guzmán, & Josse, 2022, p. 59) as presented on Figure 8. The data processed for the study is comes from a previously published map of the RAISG in 2020.

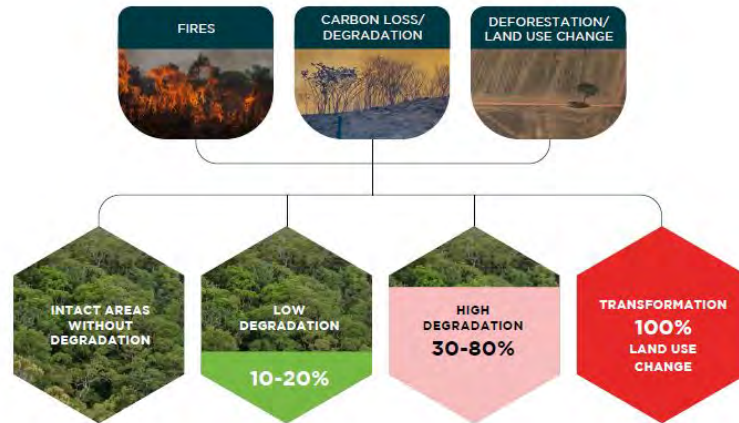


FIGURE 4.4: Degradation (Quintanilla, Guzmán, & Josse, 2022)

The Amazonia: Key Priority Areas has a simple layout consisting of a topological background and a thematic layer on the Amazonian region. The map includes standard cartographic elements. On the top right the legend of the four categories is included, additionally on the bottom left the north arrow and the scale are displayed. The map includes its title, the political boundaries and the country labels.



FIGURE 4.5: Amazonia: Key priority areas, (Quintanilla, Guzmán León, & Josse, 2022)

4.3 Selection of Conventional Map

After analyzing the various alternatives for the conventional media map selection, The Amazonia: Key Priority Areas map was chosen to be part of the user study and serve as the basis for creating the non-conventional media map. The map in question has a simple layout that allowed for the exploration of a wider variety of materials during the design of the non-conventional media map. This occurred by not having to rely on material properties that allow high precision or that must follow intricate design variables such as a wide variety of colors in the case of having numerous categories in the legend, such as the Amazonia Landcover and Landuse map by the RAISG or the Amazon Landcover map from Nasa's earth observatory. In addition, the minimalist design of the map avoids text and additional information differing from the Amazonia the Human Impact map, which represented an advantage during the comparative study with an unconventional media map, by reducing the design variables to their basic elements. Finally, the inclusion of cartographic elements

such as scale, legend, and north arrow fosters familiarity in the perception of the conventional map that was also considered in the material map design. This way, the differences in perception can be attributed or at least correlated to certain extend to the materiality of the maps, as this is the dominant variable in the design distinctions.

4.4 Proposal of Map Acknowledging Materiality

4.4.1 Design Exploration

This section examines the potential of various factors related to designing and producing a map on non-traditional media for contemporary cartography. First following the ideas of critical and post representational cartography a short overview is presented of the understanding of maps as elements determined and signified not only by its content but also to a large extent by their context. Furthermore, alternatives regarding the materials and the design of the map will be presented and justified in the lens of the materiality and cartographic possibilities. To conclude the section, the design process and construction of the material maps will be presented.

Under the empiricist paradigm of cartography maps are interpreted as objective representations of reality, nevertheless following the critical paradigm of cartography maps can be active elements able to communicate messages and lead narratives (Caquard, 2014) as it was exposed in Section 2.6. Building upon the ideas of critical cartography and following the concepts regarding materiality the material map is proposed as a object that aims to convey information not only through the data portrayed on it but also trough its physical composition, in this case trough the materials selected to compose it. Following this purpose, a revision on the map's thematic was conducted to gain a deeper understanding of the problematic being portrayed and the various narrative dimensions that could be explored and represented through the material selection of the map.

The motivation behind the map followed the interest of representing the reasons, previously presented, behind the degradation of the Amazon region. During the creative process of the map different alternatives were considered for the selection of materials that could be used to represent and convey information and connect to the aim of the map and its thematic. Materials can communicate or lead a reaction by their physical characteristics, sensorial properties and its affordances(Baxter, 2016). Materials can also enrich sensory interaction and lead to emotional responses towards objects. As it was discussed before in Section 2.5, different variables in design can lead to emotional reactions by appealing to evolutionary instincts humans have developed (D. Norman, 2003). Nevertheless materials are not limited to communicate only by their physicality but also by their symbology shaped by social constructs (Tate, n.d.).

The Table 4.1 presents different materials considered in the preliminary process of the material map design their characteristics and the relation the materials share with the topic of the map. The table is presented as an answer for the Research Questions 3.1 and 3.2 regarding which materials could be

related to the topic and in which ways they relate. Additionally, the table sets the basic information considered in the analysis for answering the Research Question 3.3 related to the suitability of the materials for the map creation.

Material	Relation to the Topic	Physical Characteristics	Cartographic Limitations	Possibilities in Design
Wood	Direct product of deforestation, remaining material of dead trees	Diverse alternatives of texture, potential for tactile exploration. Lines of the wood could serve as a design component	Difficulty of manipulation. Limited scale for data depiction	Possibility of being engraved, marked, shaped. Different woods to represent areas.
Plants	Alive material with symbolic meaning of life and representation of victims of ecosystem degradation	Organic smell, independent growth, tactile quality of leaves.	Preservation limitation. Low manageability. Time dependency for growing	Represent forested areas with alive plants and degraded with dead ones.
Leaves	Organic materials originating from trees	Soft texture, variety of color, can produce sound when being touched.	Fragility for manipulation. Easy degradation	Possibility of being marked and easily cut. Use a variety of color or livelihood for forested or degraded areas.
Meat	Product behind one reason for deforestation, livestock farming	Strong sensory affordances in texture and smell.	Preservation limitation. Strong sensorial impact (smell). Easy degradation, biological risk	Use in degraded areas as a representation of dead and cattle ranching.
Bones	Remaining matter after the death of cattle, evoke thoughts of death	Various texture, particular smell. Difficulty of manipulation.	Scale limitation for data depiction	Possibility of being marked, engraved. Use on degraded areas. Can be used to generate relief.
Plastic	Human-made material commonly related to environmental issues	Smooth texture, potential for creative manipulations, various colors.	More abstract relation to the topic	Possibility of use as a surface representing human impact, can also be manipulated to generate relief.
Coal	Represents the remaining matter of burned trees	Rough texture, potential for dark color contrasts, can cause stains when touching.	Fragility for manipulation	Represent degraded areas, offers relief effects. The color can offer an interesting contrast with other materials.
Coins	Symbolizes economic interests behind environmental impacts	Metallic texture and smell, color variations. Scale limitation for data depiction.	More abstract relation to the topic	Use as a surface representing the economic interest behind. Can be engraved but would require machinery. Can also be piled up.
Soybeans	Product behind deforestation for agricultural purposes	Grainy texture, tactile experience.	Preservation limitation	Dried beans to represent degraded areas, presented as a product. Use sprouts to represent forested areas.
Matches	Made from wood, symbolizing fire hazards and deforestation	Striking friction for lighting, potential for sound and experience resultant from ignition.	Fragility for manipulation. Potential risk	Burned ones represent the degraded areas, and unused ones can represent forested areas, symbolic of the fragility of the ecosystem.
Leather	Represents the use of cattle and its link to deforestation	Soft and supple texture, tactile experience.	Scale limitation for data depiction (depending on design)	Possibility of being engraved, marked, shaped. Different colors could represent different areas.

TABLE 4.1: Materials considered.

All the aforementioned materials could be used in map production, and many more not considered due to the limitations of the study. However, the context in which the map was going to be presented, imposes certain constraints and considerations on the decision-making process. For the facility of the coordination of the user study, the temporal dimension of the map was taken into account. Therefore materials that would represent difficulties in the conservation of the map, in its shape and composition, were excluded during the selection process. This was the case for the proposals of plants, coal, meat, soybeans, leaves, and matches as materials for the map. Nevertheless, in certain scenarios maps can be design to have a short temporal dimension. Such could be the case of presenting a map in an exhibition meant to last only some days or even minutes. Even the concept of a reduced temporal dimension of a map might be part of the message trying to be transmitted. An example of this, also in the realm of mapping environmental topics, could be a map in ice cold conceived as a representation of the climate change and its reality. Physical characteristics and affordances of the materials that can be considered inconvenient as their fragility or temporal limitations, can also be harnessed to enhance a message in a symbolic way. Nevertheless considering the context of the study this possibility was set aside.

Besides the physical factors that were considered in the material selection process, the connection of the material to the theme of the map and the concept behind it was a priority. Additionally the interest in using non-conventional materials to explore the participants' response to the map also led to the exclusion of wood, leather, or plastic as alternatives. Several factors can be considered in the selection of materials for map making. Questions arise during the process, such as: Is the map meant to last without many physical changes? What significance might the material have in the context of the users? Is the map meant to be portable, or stationary? Is there a particular sensory experience aimed to be offered? What is the purpose of the map and how important would the spatial resolution be? Finding a suitable material takes into account these considerations, which are directly related to the physical properties of the material, its affordances and the significance of the materials in their context can be some of the variables that lead to a conscious selection of materials that are meant to enhance the map by offering of a particular materiality.

The material selection process concluded when choosing coins and bones as the media of the material map given their connection to the exploration of the problematic mentioned earlier. The inclusion of coins in the map is intended to symbolize the exploitative nature of the consumer society that has capitalized on the resources of the Amazon (Pereira & Gebara, 2023). On the other hand, the use of bones is intended to highlight the link between the consumption of animals, especially cows, and the degradation of Amazonian ecosystems. The choice of bones also draws on the symbolism of bones as remnants after death, representing an element drained of its vital substance. Additionally, both materials offered physical characteristics that would support the map making process, an example of this is their durability, facilitating the following stage of the user study.

Once the initial concept of the materials was established, the exploration of the map's design and its diverse possibilities began. This exploration was guided by Research Question 4.1 "How could

the chosen materials be incorporated into the map?”. As this question was explored in the following paragraphs, additional questions arose. Some of them were where, what kind of bones and what kind of coins should be used? How could bones and coins be incorporated into the map? How much could the materials be manipulated without losing their distinctive appearance? To answer these questions, ideas derived from concepts found in the literature review were explored, combined, and contextualized in the practical exercise of creating the material map. Concepts from cartographic studies, art, and social sciences converged to result in the following guidelines for the stages of material exploration, design, and fabrication of the material map.

Following the methodological approach proposed by (Aktaş, 2018) of giving materials the opportunity of being actors with agency in the design process, special attention was directed to the characteristics each material had to offer. Therefore, the design would not be imposed over the material causing a subjugated materiality but rather a part of the design would own itself to the materials, their affordances, and physicality. An example of this was to consider the variety of shades presented by the coins. This characteristic became a fundamental part of the design, as it was used as a variable representing the grade of degradation of the ecosystems, between intact and highly degraded areas as presented in the paper map. The idea of materials as co-designers was followed throughout the different stages of design and map production.

Cartographic considerations also played a pivotal role in the decision-making process. For example, 1 euro cent coins were selected to compose the map, as reducing the size of the coins would allow a higher spatial accuracy in the map. Smaller shapes could follow the graphic representation of borders more precisely, leading to a higher spatial accuracy on the material map. The fact that the coins used are euros is merely a practical issue since the map was produced in Austria. However, it is acknowledged that these decisions between materials bring different dimensions to the interpretation of the possible symbology by future users. For example, users could wonder if the value of the coin has any meaning, or if the fact that it is an European currency is also trying to communicate something. These various interpretations might be explored from the lens of post-representational cartography and the understanding of cartography and materiality as processual (Caquard, 2014; Ingold, 2007), where maps and materials are not interpreted as simply a static object or component but as a part of a process where the cartographer and the public’s interaction under a determined environment are fundamental in the study and interpretation that map and material take.

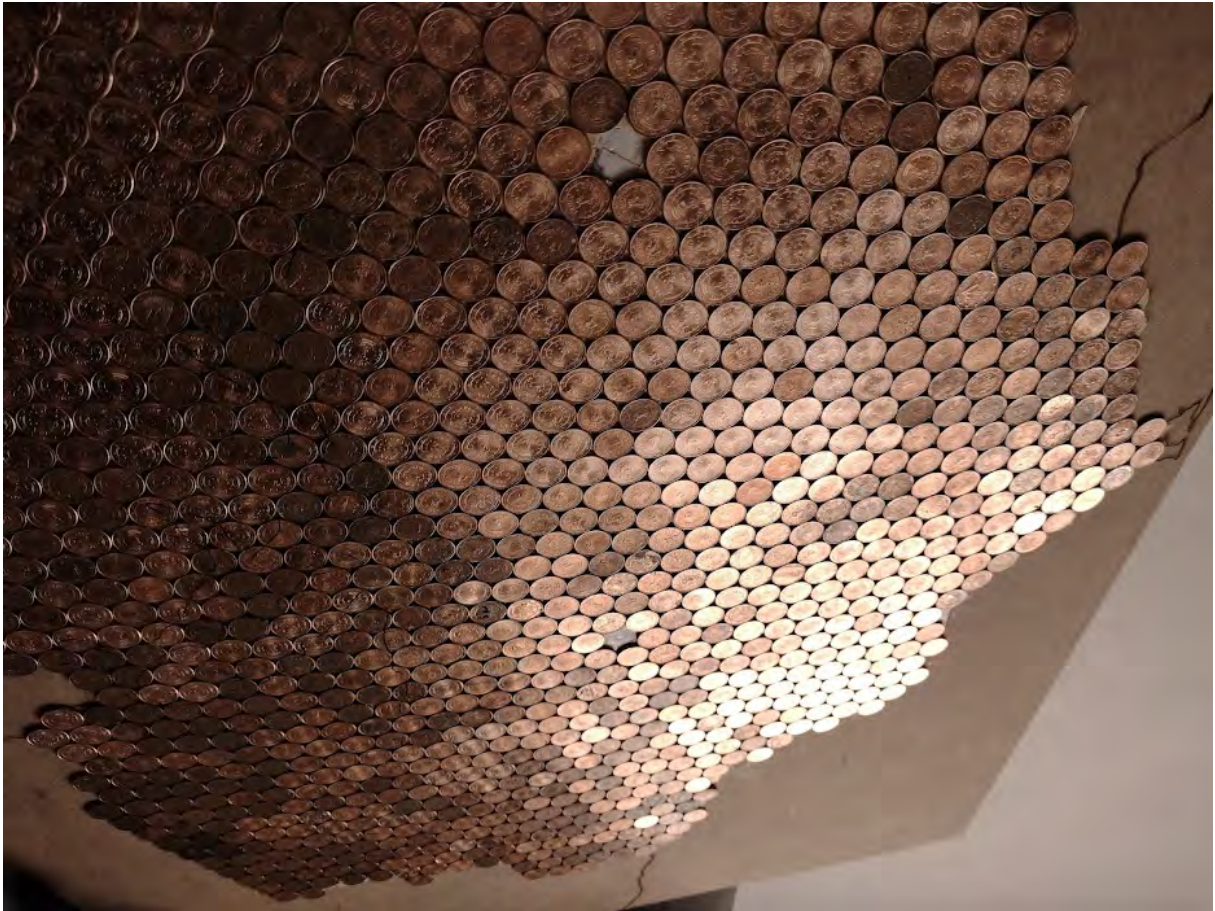


FIGURE 4.6: Coin shades

Guided by the symbolic connection under which the bones were selected, cow bones were the most direct material to represent the impact of livestock on the Amazon, since cattle ranching is precisely the activity that causes deforestation on a large scale. However, the use of cow bones in the map presented a greater challenge in terms of cartographic design, mainly due to their size and the limitations in manipulation caused by their hardness. Using big bones as components of a map led to a design compromise between size of the map and representation accuracy. Either the map had a large scale so the bones can fairly represent the data or the map had a smaller scale but is less accurate in data depiction. On this scenario, the contextualization of the map played a fundamental role in the definition of the design. Defining the map as an element that thought to awake curiosity and interest in a problematic, diminished the need for precision and prioritized the idea of the map as an abstraction that would prioritize the message over the spatial accuracy of the map. Nevertheless, in an attempt to preserve a comparability between paper map and material map, the bones were cut into thin slices to compose the patterns of deforestation in the map.

The physical transformation of the bones brings into consideration another variable when working with materials imbued with symbolism, to what extent can a material be intervened while still keeping its identity? This can depend on several factors, including the familiarity of individuals with the material, the facility to recognize, and the degree to which the material changes physically

after being intervened. This question raises broader inquiries about whether materials communicate solely through people knowing what they are, or whether they must also be perceived as such. While these questions extend beyond the scope of this study, they raise interest in exploring such ideas in future research.

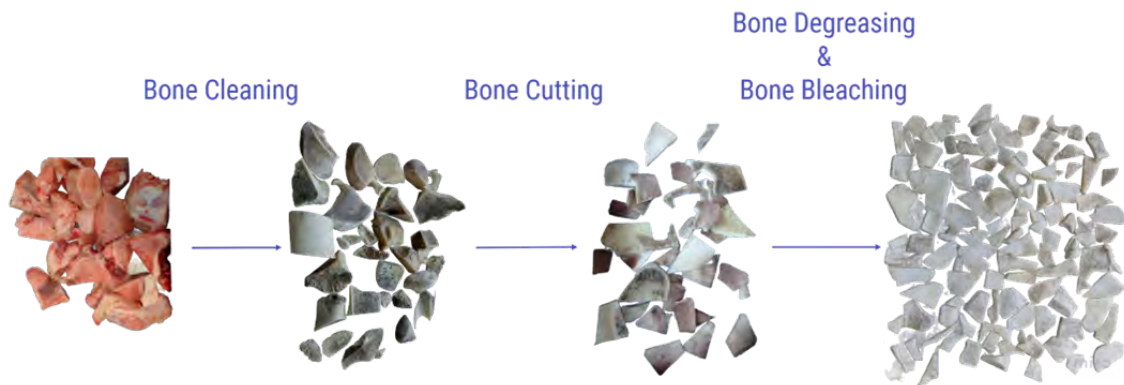


FIGURE 4.7: Bone manipulation process

4.4.2 Map creation

After establishing then one euro cent coins and cow bones as the main materials, and having an idea of how the design would incorporate the materials, the creation process started. First, a wooden base was marked with the basic elements of the map. The A1 size base of MDF (medium density fibreboard) of 8 mm was engraved using a laser cutter. The material was selected base of the map as it is commonly used in laser cutter projects, the finishing of the laser is quite clear and presents a good contrast. The MDF offered a neutral layout for the base map, where the main attention would be focused on the Amazonian Region that was composed by the previously defined materials. The countries and Amazon border as established in the paper map where included in the engraved file. Subsequently, a paper map was glued on top of the Amazon region. The map contained data from the RAISG of the deforested areas. Then the patterns of deforestation of the base map and a constant visual company of the paper map were the guides for the placing the coins that were then glued to the wood base Figure 4.8.

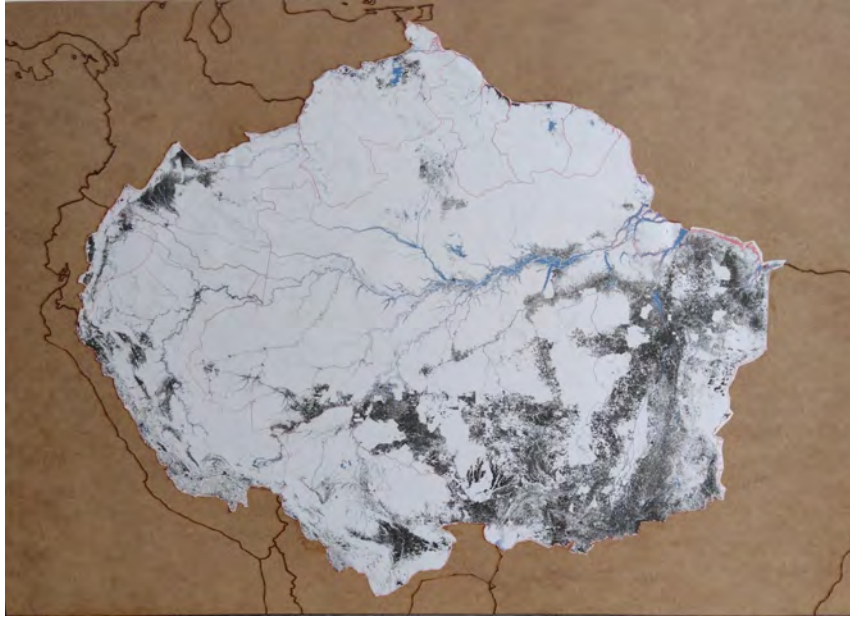


FIGURE 4.8: Base of the map

The darker coins were placed in the most degraded areas while the newest and shiniest coins were placed in the intact areas Figure 4.9.



FIGURE 4.9: Coin placement

Later on, the bones that were previously cut in thin slides of around 5 to 10 mm with a band saw, were glued in the areas of transformation trying to follow the geometry of the areas as much as the shape of the pieces of bone would allow Figure 4.10.



FIGURE 4.10: Map detail

Finally Additional elements were added to the map like an inset map, labels of the countries and oceans and the title and legend of the Map. The spaces between the coins was painted with ink in a color similar to the tone of the coins, this in order to cover the paper guide under the coinFigure 4.11.



FIGURE 4.11: Finished map

When examining maps through the processual lens of cartography, the creative process of the map becomes an interesting experience to analyze. The interaction between the map maker and the materials takes another meaning when a map is understood and as an element in process more than

as finished product only. In this sense, the experience of the cartographer is also relevant for the understanding of the map, the interaction between map maker and material becomes process of study. Furthermore, besides the exploration of the material and how the creator of the map experiences it, emotional responses can also be considered as a part of the creative process. Following the ideas of emotional mapping, emotions in maps can be studied in different stages, during the map-user interaction and also during the creative process of mapping by the related emotions of the creator of the map experiences during the mapping process (Caquard & Griffin, 2019). Therefore another effect that would be interesting to study is that of material selection during the creative process of a map, through the experience of the map-maker and their embodied experience through the interaction with the materials.

Emotional mapping is an emerging field in cartography, one of the stages of the mapping process where emotions are present is during the creative process, emotions can be independent to the map, caused as a reaction of the topic being mapped or by the technological experience during the map production (Caquard & Griffin, 2019). As exposed before material interaction can trigger emotions see (Ahmad Sayuti & Ahmed-Kristensen, 2020; D. A. Norman, 2004; van Kesteren, 2010). By incorporating alternative materials to the mapping production, emotional responses can arise in the map making process, opening an opportunity to further study by the branch of emotional cartography. In addition, recent call to consider different alternatives to enrich the narrative dimension of maps has been present in cartographic discussions, concluding for example in proposals of narrativizing the mapping process (Caquard, 2014; Peterle, 2019). As an attempt of adding to the narrative dimension of the material map also as an exploration of the effect of materials in map creation, the following section presents the experience of creator, also author of this work, during the material map crafting process. The section follows a practice-led approach where the thoughts and experiences lived during the creative process and subsequently contextualize the resulting concepts through the theoretical lens.

Applying the narrative approach followed by (Aktaş, 2018) and proposed by (Gregson, 2011) on how narrating in an informal non-conventional language strengthens the materiality of sharing personal experiences, the following section will give an insight of the interaction between map maker and materials during the creative process of the map.

4.4.3 The experience of the map-maker

While the creation of a printed map nowadays usually involves digital processes, making a map from coins and bones introduced a transformative shift in the map-making experience. Engaging with these materials provided a deeply tactile and sensory encounter that, on some level, evoked emotional responses. For example, the bone-cleaning phase was significantly more challenging than anticipated, leading to feelings of frustration and self-doubt about the decision-making process. Moments of sadness, occasionally followed by flashes of anger, arose when the bones were thought of as the remains of animals.

As I interacted with the materials, a constant sense of awe marked the initial stages of bone cleaning. This awe was triggered by the haptic interaction with the flesh attached to the bones, coupled with the contemplation of its strength. This interaction also made me think about the bigger picture – how these bones were once part of living creatures. Also, thoughts regarding the use of bone as an ancestral practice in crafting processes, led me to develop an interest in researching about related practices and the history of the use of ones in cartography also. However, as I progressed, the focus shifted from the material's significance to the sensory experience. Exploring different textures with which I was not familiarized was a part of the process, as the intricate inside of the bone that looked somehow like a sponge.

Moreover, this process made me reflect on how digital work often lacks the tangible aspect. How digital creation disconnects from the previously mentioned idea of embodiment, how we forget to touch, to sense when we only work in a virtual environment. Additionally, the long hours I spent crafting the bones and meticulously arranging them to represent deforestation patterns gave me a unique perspective. I started memorizing shapes and details in a way that would likely have been different if I were working on a digital map.

The experience lived as a map maker/crafter of the material map prompted the idea of how the experience of the creator might enrich the experience of the future user in the context of material maps, building on the idea of the relevance of narrative approaches to cartography. In addition, the interaction with the selected materials triggered a variety of thoughts and emotions, sometimes similar to the frustration that a cartographer can experience during the creative process, but sometimes very specific to the context of the interaction with the specific material, whether by the physical characteristics of the material or by its symbolic meaning.

Chapter 5

User Study Methodology

This chapter details the methodology and methods used in the final phase of the project, specifically the user study. The study setup is described, followed by the methods used for data collection, including observation during map-user encounters and a subsequent questionnaire answered by participants. Additionally, the data analysis methods are presented and described. The design and execution of the user study were underpinned by Research Questions 5.1 and 5.2, which are addressed through the development of Chapter 6.

5.1 User Study

To understand the impact of materiality on map-user interaction and perception, a comparative user study was conducted. The study involved the active participation of 23 on-site volunteers. The study environment was an unoccupied classroom where two different maps were thoughtfully displayed. Both maps were accompanied by a small tag on top of the map that indicated the materials used on each map, ink on paper for the paper map and coins and cow bones for the material map. A one paragraph explanation of the topic and Figure 4.4 were displayed on the side of the paper map, offering a contextualization for the information on legend of both maps. Each participant was allotted a private 30-minute session to engage with the maps at their own pace. During this interactive phase, detailed observations were documented by the researcher. Clear instructions were given, allowing participants the freedom to interact freely with both the paper and the material objects for as long as they wished. It was also emphasized that they could ask any questions about the objects or the topic.

Following this hands-on engagement, participants were asked to complete a questionnaire that sought their insights and perceptions based on their interactions. The study design intentionally referred to both maps as “objects” during the introduction to avoid any bias in participants’ responses. This approach ensured that their responses to the questionnaire remained impartial. In particular, the first question focused on participants’ perception of the “objects” as maps, setting the stage for understanding their interaction experience and interpretation.

5.2 Observation

The observational method employed during the interactions between the participants and the maps served the purpose of gathering information about possible haptic or other sensory interactions beyond the act of observation. The encounters between the users and the maps were observed and described. Attempts to touch the maps, to get closer to them, or any kind of observed action were documented. These sensory annotations were supplemented with questions on the subject in the survey.

At this stage, the researcher's attention was directed toward several aspects, including the duration participants spent looking at each map and their movements as they navigated around to perceive the details of each representation, such as the distance they maintained to each map. This process of observation evolved into a refined empirical practice over the course of the study, gaining clarity and depth with each encounter. A notable focus was placed on actions involving sensory exploration, such as instances where participants approached the paper map to touch it. These sensory interactions were documented, providing valuable insights into the participants' tactile experiences. In addition, participants' perspectives on their sensory encounters were obtained directly from the questionnaire, adding a layer of depth to the understanding of the sensory exploration. In addition to the sensory interactions that could be observed, all of the participants' questions about the maps and the topic of the maps were carefully recorded. This approach aimed to capture a broader range of data for later analysis under the cognitive lens of map-user interaction.

5.3 Questionnaire

The purpose of the questionnaire was to collect data from the participants regarding their interaction with the maps, their perceptions, and thoughts resulting from their encounters with the two maps. The questionnaire includes Likert scale questions ranging from 1 to 5 and open-ended questions, deriving both quantitative and qualitative data. Likert scale is a common tool in user perception surveys to gather information on opinions and behavior (Allen & Seaman, 2007; Boone Jr & Boone, 2012; De Winter & Dodou, 2010). The questionnaire see, appendix, was divided into five main sections, the first consisting of one question was the general perception of the objects as maps. The second section was the sensory interaction where the users were asked about the desire of physically interacting with the maps. The third section was the engagement section, where data about personal preferences and attraction towards both maps was collected. The fourth section was the perception section, which consisted of questions related to the impression the participants had towards the maps in terms of the information presented, additional information they might had perceived, and the possible impression of a critical call of the maps. The sixth section collected data on the emotional response the participants might have had while interacting with the maps. The questions were formulated for both maps as independent ranked responses or as a comparison between both maps. This was done to assess how the use of materials in the maps might affect the perception of map users. The seventh and final stage had questions that aimed to contextualize the participants in terms

of their previous knowledge and experience with maps, environmental problems, environmental problems of the Amazon, and visual art. The complete questionnaire, which was created using Google Forms and answered on the participants' mobile devices, can be found in the Appendix.

5.4 Data Analysis

The primary objective of the user study, as aligned with Research Objective 5, is to assess whether the deliberate selection of materials and design of materiality in a map can induce a perceptual shift in users. To achieve this goal, both the observation phase and the questionnaire were strategically designed to collect comprehensive data on participants' interactions, perceptions, and direct comparative perspectives on the maps. For the quantitative data resulting from the Likert scale approach, a statistical framework was adopted to ascertain the existence of statistically significant evidence indicating variations in answer distributions between the two maps. Consequently, a hypothesis test was performed on the quantitative data. In addition to this, to gain a thorough understanding of the collected data, a qualitative analysis of the open-ended responses was be conducted. This qualitative analysis provides contextual depth to the results and a broader range of interpretations.

5.4.1 Quantitative analysis

To initiate the data analysis process, the Likert scale responses were initially visualized in bar charts. This visualization technique was employed to provide an initial overview of the distribution patterns within the data.

For the analysis of the quantitative data collected through ranking-based questions, first a descriptive statistics analysis was conducted. In this stage the measures of central tendency were determined, in this case mean and median. There is a discussion in the research field regarding the validity of the mean as an adequate descriptor for Likert scale data, due to the definition of the data as ordinal but not necessarily with regular intervals (Allen & Seaman, 2007; De Winter & Dodou, 2010; Sullivan & Artino Jr, 2013). Nevertheless the mean was considered a relevant descriptor to show certain tendencies of the responses, therefore it was selected as a first approach to understand the distribution of the data. Additionally as an indicator of the variability of the responses, the standard deviation was calculated for a further understanding of the distribution and for comparative purposes of the analysis. The previously mentioned descriptors where calculated for every question regarding the interaction and perception of the maps.

In addition to the descriptive statistics, the Wilcoxon signed-rank test for paired data was employed. This non-parametric hypothesis test offers a comparative analysis of two distributions. The test is particularly suited for analyzing Likert scale data (De Winter & Dodou, 2010). When working with Likert scale data, there's an ongoing debate about whether to use parametric or non-parametric tests. In this study, the decision to use the non-parametric Wilcoxon signed-rank test was made to ensure a robust analysis that aligns with the characteristics of the data, without the need for assumptions

associated with parametric tests like the normally distributed nature of the data. The statistical analysis was performed in R. Questions 1, 2, 5, 6, 7 and 8 were analysed with this approach as the answers consist in two independent rankings for both maps.

The Wilcoxon test takes as a reference of the distribution the median, being suitable for ordinal data as the resulting from Likert scale rankings. The median of both distributions (both maps) are compared and a p-value results from the test application. The data is approached as paired data as it is the same sample of participants answering the questions regarding both maps, therefore every entry is correlated for paper and material map.

- Significance level (α) = 0.05

If the resulting p-value < 0.05 then the Null Hypothesis is rejected. There is statistically significant evidence to conclude the results for both maps are different.

- Null Hypothesis

The median difference between pairs of observations is zero. Therefore there is not statistically significant evidence at $\alpha = 0.05$ to conclude that the difference in the map perception is not zero.

- Alternate Hypothesis

The median difference between pairs of observations is not zero. Therefore there is statistically significant evidence at $\alpha = 0.05$ to conclude that the difference in the map perception is not zero.

The following workflow was implemented in R to obtain the p-values that were compared to the level of significance. First the data was organized in vectors, one vector for every answer, therefore the questions had two vectors, one for the paper map and one for the material map.

```
#library(psych)

QR=Results2$Q1.Paper.object
QT=Results2$i..Marca.temporalR=Results2$Q1.Paper.object
QT=Results2$i..Marca.temporal

#To what degree do you perceive the following object as a map?
PQ1=Results$Q1.Paper.object
MQ1=Results$Q1.Coins.and.bones.object
PQ1
MQ1

> PQ1
[1] 5 5 5 5 5 5 5 5 5 4 5 5 5 5 5 5 5 5 5 5
> MQ1
[1] 5 5 3 3 5 2 4 4 4 4 3 4 5 3 5 4 5 5 5 5
```

Subsequently, the Shapiro-Wilk test was employed to discard a normal distribution of the data, confirming the use of a non-parametric test as an adequate choice. As the resulting P-value is minor than 0.05, it is confirmed that the data is not normally distributed.

```
#Shapiro Test to check Normal distribution
shapiro.test(PQ1) #p-value = 3.995e-10
shapiro.test(MQ1) #p-value = 0.0001676
```

Finally, the Wilcoxon signed-rank test for paired data is applied obtaining a p-value later compared to the 0.05 level of significance, to whether accept or reject the null hypothesis and conclude regarding the possible difference between the perception of the paper and the material map. On the statistics section of the Appendix the rest of the statistical analysis on R is presented.

```
shapiro-wilk normality test
data: PQ1
W = 0.21501, p-value = 3.995e-10

> shapiro.test(MQ1) #p-value = 0.0001676

shapiro-wilk normality test
data: MQ1
W = 0.77695, p-value = 0.0001676

> wilcox.test(PQ1,MQ1)

wilcoxon rank sum test with continuity correction
data: PQ1 and MQ1
W = 382, p-value = 0.0008381
alternative hypothesis: true location shift is not equal to 0
```

FIGURE 5.1: Statistical analysis in R, workflow

The obtained results after conducting the previous methodology are presented in the 6.1 in the results section.

5.4.2 Qualitative analysis

To analyze the qualitative data derived from the open-ended responses, a thematic analysis approach was employed. This involved the development of a systematic coding strategy, where the gathered data was manually categorized. Labels were assigned to discern prominent concepts highlighted by participants, as an explanation of their ranked responses. Each open-ended answer was color-coded within an Excel table, with blue indicating references to the material map and dark yellow for references to the paper map. Following this coding process, words or concepts that appeared repeatedly and pertained to the same aspects of the maps were grouped together as thematic categories. Consequently, these categories were accompanied by their respective frequencies, offering a comprehensive view of recurring themes.

It's important to note that while the coding process served the purpose of identifying common topics, the completeness of the answers was crucial for meaningful interpretation. The entire context of the response was necessary for an integral understanding. The following table presents a segment of the aforementioned methodology, specifically addressing the open-ended complementary response for question 3.

Did you feel more drawn to a map in particular?
I felt more drawn to the material map when it came to touching it but in order to get the detail of data and understanding I went deeper on the paper map
The material map offers quite the open space to fully interact with the map. Having the opportunity to understand the map, while also navigating with the specific material .
I wanted to touch it
Changes in texture and unsual materials are particularly interesting and awake curiosity
The paper map is something one sees everyday , whilst the material map is something unique
The material map is more interesting to look at, a paper map you see all the time so it doesn't draw you in. but i've never seen a map with coins and bones before
I am familiar with it and it seems like there is more Information . I am Not really into art
I perceived both of Thema in a neutral way.
Because it's more familiar to me
because of the material , and it looks different than a usual map
Because the paper map was easier to understand , more „ normal “
because it made me nervous that it was made of bones
The paper map has a familiarity to it and features which are often used in other maps so it's easy to understand
I'm drawn to both maps, one pleases the intellect throughB8:C16 "scientificness", one pleases more the sensual and aesthetic learning.

TABLE 5.1: Coding qualitative data

After coding the open answers, as a way to visualize the data and find patterns, a word cloud graph was created. For this task, the web page <https://www.wordclouds.com/> was selected, as it allows to add manually the list of words with their corresponding weight and color as presented in the following figure.

Word list Apply ×

+
all
all

Toggle column: [Color](#) - [URL](#)

16 words Search:

	Weight	Word	Color [hex]
	6	Different	#577590
	6	Familiar	#BF8F00
	6	Senses	#577590
	5	Materials	#5F81A0
	4	Interesting	#678BAB
	4	Understand	#C69913
	2	Art	#749CC1
	2	Curiosity	#749CC1
	2	Detail	#C99E1D
	1	Conver urgent message instantly	#81AED8
	1	Information	#C59D27
	1	Optic	#C59D27
	1	Scientificness	#C59D27
	1	Sensual aesthetic learning	#81AED8
	1	Traditional map features	#81AED8
	1	Understand	#81AED8

FIGURE 5.2: Word list, question 3

The previous word list results in a word cloud that offers an overview of the mentioned themes. The resulting visualizations are presented in Section A.4 in the appendix section

Chapter 6

Results & Discussion

6.1 Observation results

The duration of participants' observations of the maps varied, ranging from approximately 30 seconds to 2 minutes and 30 seconds for each map. Although there were variations in the duration of observation of each map among participants, no consistent pattern emerged indicating a preference for one map over the other in terms of attention span. Most participants began their observation by examining the paper map, placed near the entrance to the room, before moving on to explore the material map. During their observation of the paper map, participants tended to maintain a static position, standing at a distance of between 50 cm and 1 meter, and observing the map from a fixed point of view. In contrast, interactions with the material map were characterized by more dynamic engagement, as participants frequently adjusted their positions while interacting with the map to explore various details. Occasionally, participants would move away from the material map after the initial observation, only to revisit from far both maps for comparative analysis.

In addition to visual interaction, sensory interactions also occurred. Specifically, 9 participants decided to touch the material map and, 4 of them asked permission beforehand. This interest was not manifested towards the paper map. After the observation, one of the participants manifested to have been tempted to touch the material map, but refrained on the assumption that it could not be touched due to possible future degradation of the material. Moreover, two participants leaned in to smell the material map. Some comments shared by the participants included phrases like “cow bones, crazy,” “wow, cow bones,” and “can I touch it? It doesn't look like bones.” Furthermore, participant curiosity prompted queries about the origin of the bones and the motives behind selecting those particular materials.

6.2 Perception of the Object as Map

The first question of the questionnaire was “To what extent do you perceive the following object as a map?”, from 1 “I do not perceive it at all as a map”, to 5 “I fully perceive it as a map”. In

both cases, paper map and coins and bones map, the median of the responses was 5, indicating that the majority of participants perceived both objects as maps, see Figure A.13. However, the mean for the paper map was 4.96 while for the material map was 4.26. Furthermore, while 22 out of 23 participants indicated that they fully perceived the paper object as a map, this rate drops to 12 out of 23 for the coins and bones object. This is evidenced by a standard deviation of about 0.21 for the paper object responses, compared to a deviation of about 0.91 for the coins and bones object.

Even though this particular question did not prompt open-ended replies, the participants' viewpoints on this matter were contextualized based on the insights from subsequent questions. Many participants characterized the paper map as familiar, scientific, traditional, and precise, while describing the material map as unique and artistic. Some even referred to it as art. Adopting a positivist approach when perceiving maps could explain why the material map is sometimes perceived less as map. From the positivist paradigm of cartography, maps are considered to be objective depictions of reality. This viewpoint embodies a scientific vision, that tends to prefer high spatial resolutions, and aims to represent an impartial interpretation of reality. Therefore, the abstraction arising from using non-traditional materials and their inherent design constraints may have caused the participants to regard the material map as less cartographic. Interesting considerations arise when thinking about how responses would differ if the material map was presented independently without a traditional map for comparison. Would the perceived level of perception of the object as a map alter without a comparable traditional map? Moreover, if the material map would have been presented with a map that with a more abstract or artistic character where data seems less "scientific" but the paper remains as the medium, how would have the reactions differ? These inquiries invite exploration in future research endeavors.

6.3 Inclination for Multisensory Interaction

The second question of the questionnaire was "To what extend did you feel the impulse to interact with the maps in ways beyond observing them, such as touching, smelling, or exploring them with your senses?", from 1 "I did not feel the impulse at all", to 5 "I really felt the impulse". While for the paper map the median was 1 and the mean 1.35, indicating that the majority of participants did not feel the impulse of interacting with the map in ways beyond observing it, the median for the material map was 5 and the mean 4.22, indicating that the majority of participants really felt the impulse of interacting with the map in ways beyond observing it, see Figure A.14. The standard deviation was 0.57 for the paper map responses, and 1.00 for the material map responses.

The data collected during the observation phase, combined with open-ended responses to other questions that mentioned sensory interaction, provide a basis for understanding the results. Participants frequently expressed an inclination to touch and physically interact with the material map, this is exemplified in responses such as "the interaction of other senses besides sight is more pronounced due to the tactile qualities of the material used in the map." These responses evidence an impulse, in some of the participants, evoked by the materiality of the map. Contrary, there was a lack of desire for haptic interaction exhibited toward the paper map, where visual engagement prevailed.

Taken together, the findings from the observation phase and the participants' responses provide a comprehensive account of the multisensory dimension of the participants' interactions and their engagement with the innovative materials integrated into the material map.

The overview of these results offers an intriguing approach to the cognitive lens of cartography when the concepts of material engagement and embodied mind are considered (Malafouris, 2013; Varela et al., 1991). The acknowledgement of the cognitive process through the embodied mind brings interesting views on the possibility of expanding the ways in which people can interact with maps and think through sensory interaction, going beyond a mere visual element and its interpretation. Several authors have mentioned the interest in adding sensory dimensions to spatial information and the possibilities this brings to spatial cognition (Kent, 2019; McLean, 2020; Olmedo, 2018; Rossetto, 2019). It is directly the materiality of the map through its sensory affordances that allows for the diversity of the user's sensory experience. Therefore, considering this, materials represent a fundamental variable in the research of sensory mapping and cognitive cartography.

6.4 Inclination for a Specific Map

The third question took a comparative approach, diverging from the previous two that inquired about each map individually. The question was "Did you feel more drawn to a map in particular?" where 1 was "I felt particularly drawn to the Paper map, and 5 was "I felt particularly drawn to the Material map", see Figure A.15. The median of the responses was 4 and the mean 3.56, showing that that more participants felt particularly drawn to the material map. The standard deviation of the responses was 1.04. Only 3 participants provided answers of 1 or 2, indicating a preference for the paper map. In addition, 7 participants reported an equal level of interest in both maps by selecting 3 as a response, leaving 13 participants that chose responses of 4 and 5, suggesting a stronger attraction to the material map.

Among the explanations provided by participants regarding their interest in the material map, several common themes emerged. Participants noted factors such as the fact that they wanted to interact with the map due to the material, the texture and the uniqueness and uncommonness, stating it was something different to what they were use to see. One participant noted, "The material map has a uniqueness and a type of artistic value that I have never seen before, while also keeping 'traditional map' features such as an inset map". Another participant states "changes in texture and unusual materials are particularly interesting and awake curiosity".

On the contrary, arguments favoring the paper map were often related to a sense of familiarity. Some participants perceived the paper map as a more usual or normal, also as easy to understand and more detailed. This perspectives are evidenced in answers like "The paper map has a familiarity to it and features which are often used in other maps so it's easy to understand".

A word cloud visualization of the coded open-ended responses is presented in A.25, which provides a comprehensive snapshot of participants' sentiments. This word cloud was generated according to the methodology outlined in the qualitative analysis section, where the size of each word corresponds

to its frequency of mention within the responses. Yellow coded words are associated with the paper map, while blue coded words are associated with the material map. This color coding will remain consistent throughout the subsequent results.

To conclude this section, it is derived from the participants' responses that there is a particular interest in the material map that is primarily driven by the awe effect of the difference in the physicality of the map compared to more traditional map media. This novelty drew the attention of participants, however, it also presented challenges in interpretation due to its unfamiliarity. Furthermore, some users perceived the paper map to offer more detailed data representation due to the medium's allowances. Additionally, the use of materials raises questions about the rationale for their inclusion. This observation underscores the potential of materials as tools setting a context or communicating, how the story of the material could enhance the depiction of the topic or message behind the map.

6.5 Information Similarity Between Maps

For the forth question was also a comparative question. The participants were asked "Did you feel both maps conveyed similar information?" where 1 was "completely different information" and 5 "very similar information", see Figure A.16, the median of the responses was 3, the mean 3.30 and the standard deviation of the responses was 0.88. This indicates a slightly positive skew towards perception of information similarity. The word cloud visualization resulting from the coding exercise conducted on the qualitative data that complemented the ranked answer, is presented in Figure A.26.

Following participants' explanations of the perceived information similarity between the two maps, several patterns emerged. Participants reported a higher level of detail in the paper map. Elements such as country borders were noted in the perception of the paper map. Terms such as accuracy, detail and precise were mentioned when referring to the paper map. In addition, the distinction between the low degradation and high degradation on the paper map legend and the absence on the legend on the material map was noted.

Participants acknowledged the comparability of the information presented on both maps. Some participants noted that despite differences in texture or presentation, both maps effectively conveyed areas of transformation and deforestation. One participant highlighted that "both were conveying the same topic, the level of detail and content complexity was different."

Participants also mentioned differences in focus and perspective created by changes in color and texture. One participant noted, "The natural colors of the material map do not convey information in the same way as the texture does. I was primarily drawn to the 'Transformation' area on the material map, whereas the paper map drew me to areas of intactness and low degradation as well". In addition, some participants focused on the difficulty that the color change in the coins presented in distinguishing changes in the degradation of the area.

Although the majority of responses justified the differences or similarities in terms of the more conventional elements of the map, such as legend, spatial accuracy, color, and borders, one participant

mentioned that “while the paper map shows the extent of deforestation or change in landscape information based on the intensity, the material map shows the actual cause of the deforestation, as in the industry or the element. That is a huge change in terms of understanding what causes a certain phenomenon” evidencing a more abstract interpretation of the differences between the maps and demonstrating a recognition of the symbolism carried by the materials. This perspective offers another glimpse of the possibilities of material use as a tool of communication in map narratives. Nevertheless, the generality of the responses still evidence the strong influence of the more direct interpretation of the traditional cartographic components over the more abstract interpretations of the material significance in the map.

6.6 Additional Information in Maps

On the fifth question the participants were asked “Do these maps convey additional information beyond what is listed on the legend?” where 1 was “Does not convey additional information” and 5 “Conveys significant additional information”, see Figure A.17. The question was asked for both maps individually as the first and second question. The median of the responses was 3 for both paper and material map. The mean for the paper map was 2.91 and for the material map 2.65. Additionally, the standard deviation for the responses of the paper map was 1.38 against 1.15 for the responses for the material map. The word cloud visualization of the qualitative data is presented in Figure A.27.

Some participants mentioned that the material map offered a particular perspective of the topic, they pointed out that the map communicated reasons behind deforestation. Through the interpretation of the significance of the materials used on the map, the participants mentioned their perception of having understood the underlying causes of the problematic represented on the map. One participant mentioned, “The material map explains in a broad sense the reasons behind deforestation using bones and coins, offering a distinct insight into the issue.” Another participant highlighted that “The materials used were probably chosen to represent something (degradation with bones as dead material; coins as a critique for the exploitation of the rainforest - monetary value)”.

On the other hand, participants stated that the additional information presented on the paper map was mainly in the geographic elements it depicted such as rivers, borders, and mountain areas. Additionally participants also mentioned the higher spatial accuracy that the paper map offered.

Predominantly, participants reported perceiving more information on the paper map. They justified this by citing the level of detail of the geographic data and cartographic elements, such as labels and borders. This suggests that the term “information” is being interpreted from a scientific and technical perspective. Nevertheless, some participants developed a more indirect approach by deducing additional ideas from the material’s significance, demonstrating the recognition of a symbolic weight of these elements. These results continue to support an interest in the potential for further research in material selection and use as a cartographic communication tool.

6.7 Engagement in Critical Reflection

The sixth question, asked individually for both maps was “How much do these maps involve you in a critical reflection about the topic presented?” being 1 “Not at all” and 5 “Very much so”, see Figure A.18. The responses for both paper and material map had a median of 4. Moreover the mean for the paper map was 3.74 and for the material map it was 3.96. The standard deviation was 1.05 for the responses regarding the paper map, and 1.19 for the ones regarding the material map. The word cloud visualization of the qualitative data is presented in Figure A.28.

Derived from the insights shared in the open-ended responses, participants’ insights converged on several themes about the role of the maps in stimulating critical thinking. A frequent sentiment was that the inclusion of symbolic materials, such as bones and coins, in the material map provided a stimulus for critical reflection. Participants noted that the use of these materials made explicit the reasons behind the Amazon’s degradation. One participant remarked, “The bones and coins make much more explicit the reasons of the Amazona’s conditions which makes you have a critical eye on it”. Another participants states “the material map shows the consequences through bones, as well as the capitalistic reason behind it”.

In addition, participants mentioned emotional responses evoked by the material map. One participant mentioned that “the material makes me angry about the people-made transformation (destruction)”, thus demonstrating the role of the materials in the perception of the map after the interaction. Connecting to the reasons delved by the symbology of the materials, another user states, “It catches you on an emotional side and adds the reasons behind it”. However, opinions differed on the extent to which the material map provoked critical reflection. In contrast to these sentiments, one participant offered a contrasting view, stating “the coin map makes it more fun, not easy to get the critical message”.

Turning to the paper map, participants identified the role of the color palette of the paper map in evoking critical reflection. The use of red color in the paper map for the transformed areas was interpreted as a signal of danger and emergency by 4 of the participants, all of whom favored the paper map in this section. Additionally, some respondents also noted the role of green as a realistic representation of the forest or as a color evoking safety. Moreover, mentioned the facility in the interpretation of the paper map as an element that facilitated an involvement in critical thinking.

Overall, through the insights given by the users, it is possible to see that both maps had characteristics that, according to the participants, invited to a critical reflection. Not only the topic invites to have critical opinions, but the physical characteristics of the map also led to this. On the side of the material map. The selection of materials aroused thoughts about the reasons behind the degradation trough the symbolic meaning of the materials. This results invites again to consider the allowances of materials as a component that has the potential of communicating by itself and not only through the shapes it supports. On the other hand the variable that was highlighted the most in the paper map was the use of colors and how red and green are commonly related to positive and negative.

6.8 Trust Level in Maps

With the last question regarding the perception of the maps, the participants were asked “How much do you trust these maps?”, being 1 “Not at all” and 5 “Very much so”, see Figure A.19. Once again the question was asked for both paper and material map individually. For the responses regarding the paper map, the median was 5 against a median of 4 for the answers regarding the material map. The mean for the paper map was 4.78 against a mean of 3.30 for the material map. Additionally, while the standard deviation was 0.42 for the paper map responses, it was 1.18 for the material map responses. This results evidence more variability in the the thrustworthiness of the material maps according to the perception of the participants. The word cloud visualization of the qualitative data is presented in Figure A.29.

Delving into participants’ perspectives regarding the level of trust in the presented maps, it is possible to observe an approach to the trustworthiness of the maps from the spacial accuracy that the paper map offered. A frequently expressed sentiment can be derived from the concepts as accuracy, scientific character, precision, detail and exact that the participants used to describe the paper map. Additionally, the paper map was referred to as formal and traditional. Furthermore the participants mention the familiarity towards the paper map as it was an element similar to what they see regularly. One participant mentions “The Material Map does not include borders in its entirety. Moreover, it’s hard to imagine that the bones can be as accurate to depict small angles, as lines would have been”. Moreover the participants mentions the limitation of the materials composing on the material map in the spacial accuracy it could depict.

The uniqueness of the map and its artistic nature, as pointed out by some participants, was also a variable in the trustworthiness of the map as perceived by the users. According to one participant “the artist had some freedom to place the coins and bones. If you wanted, you could easily place more bones than needed”. The participant’s mention of the mapmaker as an “artist” underscores the understanding that for the participant the map goes beyond a purely factual representation. Viewed also as a creative element, perceived a different level of trust on the material map.

After analyzing the qualitative data, prominent characteristics frequently mentioned by participants align with the positivist paradigm of cartography. The trust levels that the participants had towards the maps were mainly associated with their perception of spatial accuracy and precision, traditional attributes in the perspective of maps as objective representation of the observed reality. Multiple participants accentuated the scientific and conventional nature of the paper map, which led to their greater reliance on these characteristics. According to their perceptions, the use of alternative materials restricted the trustworthiness of maps, which is consistent with the positivist approach. However, some subtle hints of the critical paradigm were evident, as observed in responses, such as “All maps are biased in a way because they are made by people that are biased so I would never trust a map 100%”.

It also results interesting to notice the distinct viewpoints emerged, indicating a clear boundary between maps and art. Participants commented that “the material map is more like an art piece to me

than a means to communicate information” or “the material maps seems like art while the paper maps seemy to be more scientific”. These viewpoints once again highlight the presence of the positivist paradigm, which becomes evident through participants’ epistemological approaches to their own perspectives on maps. Interestingly, these points of view were expressed by participants who indicated they “fully perceived” both paper and material maps as maps. This nuanced perception, where maps are perceived to possess artistic qualities while still being considered maps, caused certain participants to display a reduced level of confidence in what they perceived as being the more artistic map. This position draws an interesting contrast to the International Cartographic Association’s (ICA) definition of cartography as “the discipline dealing with the art, science and technology of making and using maps”.

In conclusion, the discussion on trust perceptions of both paper and material maps and considering the role of materiality, it is important to consider the implications of alternative material maps for trustworthiness. Given the influence of the positivist paradigm that was prominent among respondents, a challenge arises: How can maps composed by alternative materials, which might have limitations in representing precise data, inspire trust? One respondent’s perspective offers one approach on this issue, when mentioning to trust the material map because of the time spent by the artist. However, the exploration of materiality as a cartographic design variable challenges the conventional essence of trust in cartography, particularly when it comes to crafting and moving beyond digital production. This examination raises questions about the foundations of trust, particularly when approached solely through a positivist lens.

6.9 Emotional response to the maps

For the final question regarding the maps, the participants were asked “How strong is your emotional response to these maps (e.g. happiness, sadness, fear, anger, surprise or disgust)?” where 1 was “Inexistent” and 5 was “Very strong”, see Figure A.20. The median for the paper map related responses was 3 with a standard deviation of 1.24 against a median of 4 with a standard deviation of 1.27 for the material map related responses. The mean for the paper map was 2.91 against a mean of 3.39 for the material map. Additionally 20 out of the 23 participants assigned different levels of emotional response for the two maps. The word cloud visualization of the qualitative data is presented in Figure A.28.

The participants’ emotional responses to their interactions with the maps were characterized by a range of sentiments, including sadness, anger, worry, and fear, which emerged as common reactions to both maps. Additionally, some participants noted feelings of curiosity and surprise when engaging with the material map. Notably, 19 out of the 23 respondents conveyed distinct emotional reactions to both maps. For instance, one participant’s experience exemplified this variance, the participant described feeling a combination of arousal and sadness while engaging with the paper map, yet noted that their interaction with the material map triggered anger as an emotional response.

The emotional response to the maps is considered in this case a mix of reactions to the topic presented

on the maps, to the design of the map and the material expression of it or materiality, including in this last variable the use of the selected materials. From the resulting perceptions shared by users it is possible to infer that the material does play a role on the response as the topic of the map is the same and both maps follow a simple cartographic design in terms of the cartographic elements they present, (legend, tags, scale, inset map). In product design materials are recognized as elements that evoke emotional responses (Karana, 2009). Materials can be the trigger of emotional responses by their sensorial properties and by their role in society. In a study performed by (Crippa et al., 2012) compared the emotional responses of users when interacting with bowls of different materials as glass, stone, metal, rubber, mother pearl and more. The study showed that although the emotional response resulting from the material recognition is low, the materials triggered different emotional responses, participants reported to feel positive and negative emotions towards the materials as satisfaction, joy, fascination, surprise, dissatisfaction and boredom. When it comes to the study of emotional responses evoked by materials in map design more variables influence this response leading to a more complex interconnection of the phenomena and its analysis. Furthermore the intentions of the selection of materials on the material map are directly connected to the topic of the map, this led participants to reflect on the role of the materials on the context of the Amazon degradation, resulting in statements like “The materials used were probably chosen to represent something (degradation with bones as dead material; coins as a critique for the exploitation of the rainforest - monetary value)”. Materials open a world of possibilities in map design as they represent a new dimensionality of adding meaning through their sensorial affordances and through their social connotations, such is the case of the bones in the material map to which some participants mentioned “it made me nervous that it was made of bones”.

Emotional responses to maps can be considered a combination of reactions arising from different aspects, including the subject matter depicted on maps, the design composition of maps themselves, and the material expression or materiality embodied in maps. Within this range of responses, the effect of material emerges as a recognizable factor, even when the maps’ thematic content remains stable, and both maps follow a fundamental cartographic design that includes regular elements like legends, tags, scales, and inset maps. In the field of product design, the significance of materials in evoking emotional responses has been recognized, with materials often acting as emotional triggers due to their sensory properties and social significance (Karana, 2009; D. A. Norman, 2004). For example, a study by (Crippa et al., 2012) analyzed emotional reactions of users when interacting with bowls made of various materials, such as glass, stone, metal, rubber, mother-of-pearl, and others. Although the study suggested that there were low emotional responses generated by material recognition, it exposed a variety of clear emotional reactions incited by different materials. The respondents conveyed experiencing favorable emotions like satisfaction, joy, fascination, and surprise, alongside negative emotions, including dissatisfaction and boredom.

Studying material-induced emotional responses in the context of map design introduces several complexities. Here, several variables intertwine intricately, shaping the phenomenon and its interpretation. The selection of materials in the material map is closely linked with the subject matter of the map itself. This link pushes participants to think about the materials’ importance in the

wider context of Amazon degradation. As a result, this engagement made participants ponder the significance of materials. They made statements such as, “The materials used probably represent something (bones for degradation or coins as a criticism of rainforest exploitation - monetary value).” This derived thoughts resulting from the interpretation of the significance of the material also derive in changes in the emotional experience. Materials in the domain of map design offer various possibilities by introducing a new meaning dimension through their sensory characteristics and social connotations. For instance, the bones used in the material map made some participants nervous, prompting them to express sentiments like “it made me nervous that it was made of bones.” This underscores the ability of materials to evoke a range of emotional responses, contributing to a more diverse interpretation of the maps and their message.

6.10 Hypothesis test

Wilcoxon Signed-Rank Test	Q1. Perception as a map	Q2. Impulse of interaction	Q5. Additional Information Perception	Q6. Invitation to Critical Reflection	Q7. Trust	Q8. Emotion
p-value	0.004995	0.00002311	0.4635	0.6218	0.0002422	0.2319
Hypothesis	Alternative	Alternative	Null	Null	Alternative	Null
Assumption	Different	Different	Not Different	Not Different	Different	Not Different

TABLE 6.1: Wilcoxon signed-rank test results

After conducting a The Wilcoxon signed-rank test, presented in Quantitative Analysis the results are summarized in Table 6.1. The obtained results indicate that at the level of significance of 0.05, the difference in the perception between both maps for the following items by the participants is statistically significant.

- Perception of the object as a map
- Impulse of interaction
- Trust on the map

Counter to this, following the obtained results, the difference between the paper map and material map perception under a level of significance of 0.05 is not statistically significant. Therefore, it is not possible to state that statistically the perception of the users changes notably in the following items.

- Additional information perception
- Invitation to a critical reflection
- Emotion

Chapter 7

Conclusion & Outlook

7.1 Conclusion

The aim of the user study was to evaluate and analyze the potential of materiality in cartography. For this purpose, the possibilities and effects of a conscious selection and use of materials throughout the mapping process were studied in different stages, from the conception, design and creation of a map to the subsequent user-map interaction. To accomplish this a literature review was conducted. On this stage Research Objectives 1 & 2 were reached. The literature review offered a wide overview of the concept of materiality and the interest of its study in the field of social sciences, cognitive sciences, visual arts and design. In addition, the interest of engaging with these concepts from a cartographic perspective was discussed.

In the realm of social sciences the study of materiality came from a change in its paradigm which was an emphasis in the role of objects in shaping human behavior, culture and social interaction. In media studies the media and its physical properties were recognized as an element shaping social connotations and the way civilizations developed. From the perspective of cognitive science, Material Engagement Theory emphasized how the material world plays an active role in cognitive processes and how the discussion shifts from how we think about things to how we think through things, recognizing the human mind as embodied and not limited to the brain. In art, materiality is recognized as a dynamic agent that contributes to the meaning of artworks through the affordances in sensory experience and through the symbolism of materials. In design, the materials used in a product are understood as agents that can shape the user's behavior, emotional response, and perception of an object, thus materiality is recognized as a key variable in design. While cartography has traditionally focused on practicality, recent artistic experimentation with maps suggests the potential for expanding the use of materials in cartography and the interest in adopting materiality as a variable in the cartographic process.

Furthermore, a case study and a conventional media map were selected. The map, later printed on paper, was used as a base for the creation of a map that explored its materiality as a design variable. On this stage Research Objectives 3 & 4 were reached. Alternatives of materials were considered

due to the material significance in relation to the mapped topic, the environmental degradation of the Amazonia. Moreover, an analysis was performed of the physical properties of the materials, its affordances and its cartographic possibilities in map creation. This step led to the selection of two materials, cow bones and one cent of Euro coins, that became be the main components of the map. Subsequently, the design process of the map and its crafting followed a process that combined cartographic design and artistic exploration. Following the recent cartographic interest of combining mapping processes and narratives from the map maker, the experience of the design and the creative process was shared from the perspective of the maker. This as an approach to enhance the understanding of the map from a processual lens, were the experience of the cartographer enhances the understanding of the map through the creative context. Additionally, insights were shared regarding how the use of different materials on map creation influence the way the map maker experiences the creative process, from a physical and cognitive lens. On this stage the concept of the material as a co-designer (Aktaş, 2018), followed in the realms of design and craft, was explore.

For the last stage of the project a user study was conducted with 23 participants. The comparative study presented both paper and material map to the users. The encounters were individual and free in terms of the way participants could interact with the maps. The interactions were observed and noted. Subsequently, the users responded a questionnaire with ranked and opened questions. The qualitative and quantitative data of the questionnaire collected the participants' insights regarding their perception, opinions, understanding and responses to both maps. The data was analyzed through statistical and qualitative methods. On this stage Research Objective 5 was reached.

On the observation stage of the user study, it was possible to notice how some participants felt drawn to physically engage with the material map by touching it, action that was not observed towards the paper map. Additionally, some participants shared their interest on the production of the material map and the materials used. The way the participants moved to observe both maps was also different, for the paper map the observation was done by a static position of the participants, for the paper maps some participants moved around the map and got closer and further to observe the map. The time spent by the participants on each map did not present a notable different or pattern when comparing both maps.

The statistical analysis on the quantitative data concluded that there is a statistically significant difference in 3 of the items of the study, between to the paper map and the material map. First the perception as a map of both paper and material maps. Also, the impulse of interaction the participants felt towards both maps. Finally the trustworthiness perceived towards both maps. On the other hand, there was not enough statistical evidence to affirm that there is a difference in the results regarding 3 other items of the study. This are the perception of additional information in both maps, the invitation to a critical reflection and the emotional response.

Moving beyond the limitations that quantitative results represent, the qualitative analysis offered valuable insights into how participants interacted with and perceived both maps. There was a notable interest in the material map due to its non conventional materiality. In discussions about the presented information, questions arose concerning the role of the chosen media in influencing

the accuracy of spatial data, which contributed to a lack of trust for some users in the material map, possibly rooted in a positivist view of cartography and the high accuracy available in a digital era. Furthermore, the interest in sensory interaction, caused by the selection of materials of the map, aligns with the concepts of an embodied mind. It also supports the growing interest of some cartographers to incorporate sensory experiences into user-map interactions, emphasizing the relevance of materiality in this exploration. Regarding emotional responses, a discernible difference was noted in the emotions evoked by each map, indicating the ability of materials to alter emotional reactions in these encounters. However, it is important to note that evaluating this aspect was challenging due to the inherently emotional nature of the environmental issue being addressed. Another interesting perspective mentioned by some participants was the perception of the materials as elements that were communicating the causes behind the topic. These findings support the rationale for continued exploration into using materials as variables to convey information. Through purposeful selection, they can enhance the message a map intends to communicate, similar to the use of materials in visual arts.

The obtained results can be easily related to concepts mentioned previously in the literature review. The interest of multisensory interaction was evident in the encounters, motivating future studies of the role of materials in cognitive processes under the embodied mind concept. Further studies could build knowledge on the way multisensory interactions, offered by alternative materialities in maps, affect the cognitive process derived of map-user encounters. Furthermore, the potential of materials as carriers of meaning also emerged in the participants' responses. These results justify the interest in future studies of the potential of material significance in the communicative dimension of maps. The thought of exploring digital creation with alternative materials also derives from the frequently mentioned lack of precision of a material map. Nonetheless, it remains pertinent to investigate the differences in perceptions of such maps created through manual methods versus those crafted using digital technologies. The current project lays the foundation for numerous avenues of further exploration in the study of materiality in cartography.

7.2 Future Research

This research serves as an initial exploration of the potential implications of materiality of maps through different stages of the mapping process. Numerous avenues for further investigation and development of this study could be followed. Here some of them are shared:

- **Personal Context analysis:** Analyse the relation between the perception of the role of the materials of the maps and the personal context of the participants. The data collected in the user study allows a first approach to this aspect. However, due to time limitations the analysis was not conducted in the extent of the current study.
- **Eye tracking analysis:** Investigate the gaze patterns when interacting with maps composed of different materials. Explore potential variations in the observation patterns between conventional and alternative media maps.
- **Embodied experience of the mapper:** Analyze in depth the effect of material manipulation in the map maker experience, derived from the map production process.
- **Material effects on an individual map:** Investigate the impact of materials on the perception of an individual map. Studying a map in particular without a conventional media equivalent could result in differences in the perception, by avoiding an direct comparison.
- **Material-topic relations:** Explore how map materials are perceived concerning the specific topic they represent. Assess whether the contextual relevance of the topic influences the interpretation of the materials.
- **Technical material exploration:** Conduct technical research to expand the possibilities of employing various materials from a cartographic perspective. Investigate novel materials and their potential applications.
- **Spatial cognition and navigation:** Study the effects of using different materials in maps within the context of navigation and spatial cognition. Assess how material choices impact users' ability to navigate and comprehend spatial information.
- **Digital vs. physical maps:** Compare the perception of an alternative material map in physical media to a digital map representing the same materials. Investigate the role of haptic interaction and general perception. Additionally, compare user perception of manually crafted alternative material maps with alternative material maps produced using digital technologies. This in order to understand how the changes in the materiality caused by the production method, and the symbology of manual or digital work affect the user's perception.

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Appendix A


Appendix

A.1 Questionnaire

To what degree do you perceive the following object as a map? *

Paper object

MAP 1: AMAZONIA: KEY PRIORITY AREAS: INTACTNESS, LOW DEGRADATION, HIGH DEGRADATION AND TRANSFORMATION




1 2 3 4 5

I do not perceive it at all as a map ☐ ☐ ☐ ☐ ☐ I fully perceive it as a map

70

FIGURE A.1: Question 1.a

Coins and bones object *



1 2 3 4 5

I do not perceive it at all as a map ☐ ☐ ☐ ☐ ☐ I fully perceive it as a map

[Back](#) [Following](#) [clear form](#)

FIGURE A.2: Question 1.b

Sensory Interaction

Although the objects might deviate from the traditional concept of maps, from this point on we will refer to the objects as "Paper map" and "Material map."

To what extend did you feel the impulse to interact with the maps in ways beyond ^{*} observing them, such as touching, smelling, or exploring them with your senses?

Paper Map

12345

I did not feel the impulse at all☐☐☐☐☐I really felt the impulse

Material Map ^{*}

12345

I did not feel the impulse at all☐☐☐☐☐I really felt the impulse

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FIGURE A.3: Question 2

72

Engagement

Did you feel more drawn to a map in particular? *

1 2 3 4 5

I felt particularly drawn to the Paper map ☐ ☐ ☐ ☐ ☐ I felt particularly drawn to the Material map

Briefly explain why. *

Your answer

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FIGURE A.4: Question 3

Perception

Did you feel both maps conveyed similar information? *

1 2 3 4 5

Completely different information ☐ ☐ ☐ ☐ ☐ Very similar information

Briefly explain why. *

Tu respuesta

FIGURE A.5: Question 4

Do these maps convey additional information beyond what is listed on the legend? *

Paper Map

1 2 3 4 5

Does not convey additional information ☐ ☐ ☐ ☐ ☐ Conveys significant additional information

Material Map *

1 2 3 4 5

Does not convey additional information ☐ ☐ ☐ ☐ ☐ Conveys significant additional information

Briefly explain why. *

Tu respuesta _____

FIGURE A.6: Question 5

How much do these maps involve you in a critical reflection about the topic presented? *

Paper Map

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much so

Material Map *

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much so

Briefly explain why. *

Tu respuesta

FIGURE A.7: Question 6

How much do you trust these maps? *

Paper Map

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much so

Material Map *

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much so

Briefly expand *

Tu respuesta

FIGURE A.8: Question 7

How strong is your emotional response to these maps (eg happiness, sadness, fear, *
anger, surprise or disgust)?

papermap

	1	2	3	4	5	
inexistent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very strong

emotion: *

Your answer

Material Map *

	1	2	3	4	5	
inexistent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very strong

emotion: *

Your answer

[Back](#)[Following](#)

clear form

FIGURE A.9: Question 8

Context

Do you regularly engage with environmental topics? *

☐ I'm not interested in following environmental topics

☐ Sometimes I see the headlines about environmental topics

☐ I actively try to be informed about environmental topics

☐ I am informed about environmental topics and I actively participate in discussions and demonstrations related to it.

Did you have prior knowledge of the environmental problems in the Amazonia? *

☐ I had no knowledge about any environmental problem in the Amazonia.

☐ I knew there were some problems in the Amazonia like deforestation.

☐ I knew the problems in the Amazonia and the main drivers of these like livestock, soy, mining...

☐ I am an expert on the environmental problems on the Amazonia.

FIGURE A.10: Questions 9 and 10

How familiar are you with maps? *

- ☐ Not familiar at all, I don't interact with maps
- ☐ Somewhat familiar, I know the basics about maps
- ☐ Familiar, I feel comfortable interpreting maps
- ☐ Very familiar, I study or work in something related to maps

How familiar are you with visual arts? *

- ☐ Not familiar at all, I don't interact with visual arts
- ☐ Somewhat familiar, I sometimes interact with visual arts
- ☐ Familiar, I often interact with visual arts
- ☐ Very familiar, I study or work in something related to visual arts

FIGURE A.11: Questions 11 and 12

Additional thoughts

Here you can expand on any ideas related to the questionnaire.

Your answer

[clear form](#)

FIGURE A.12: Question 13

A.2 Bar Charts

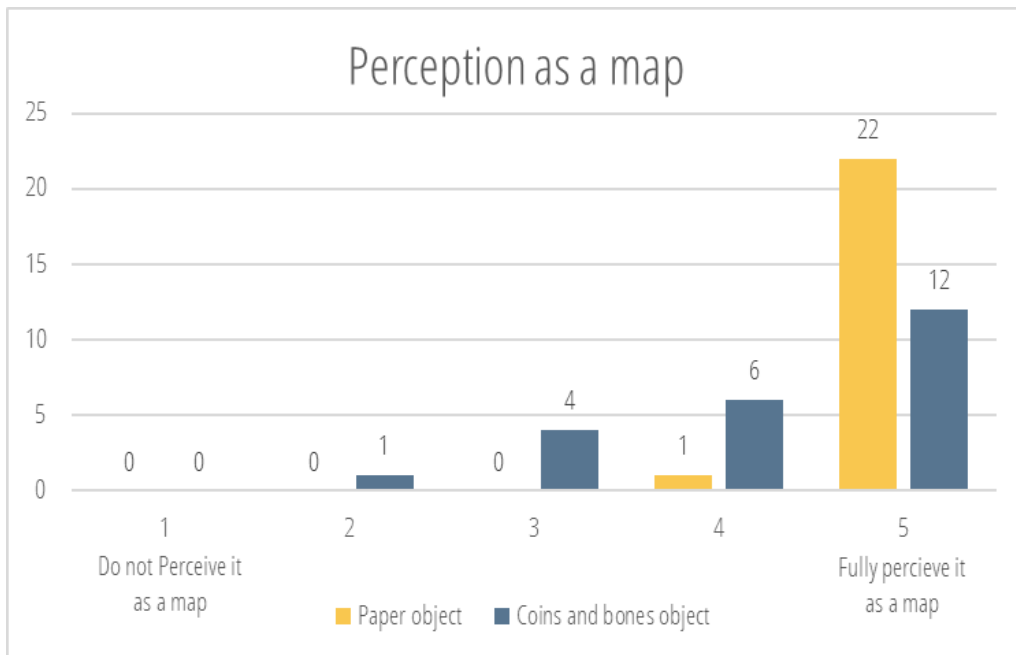


FIGURE A.13: Bar Chart 1

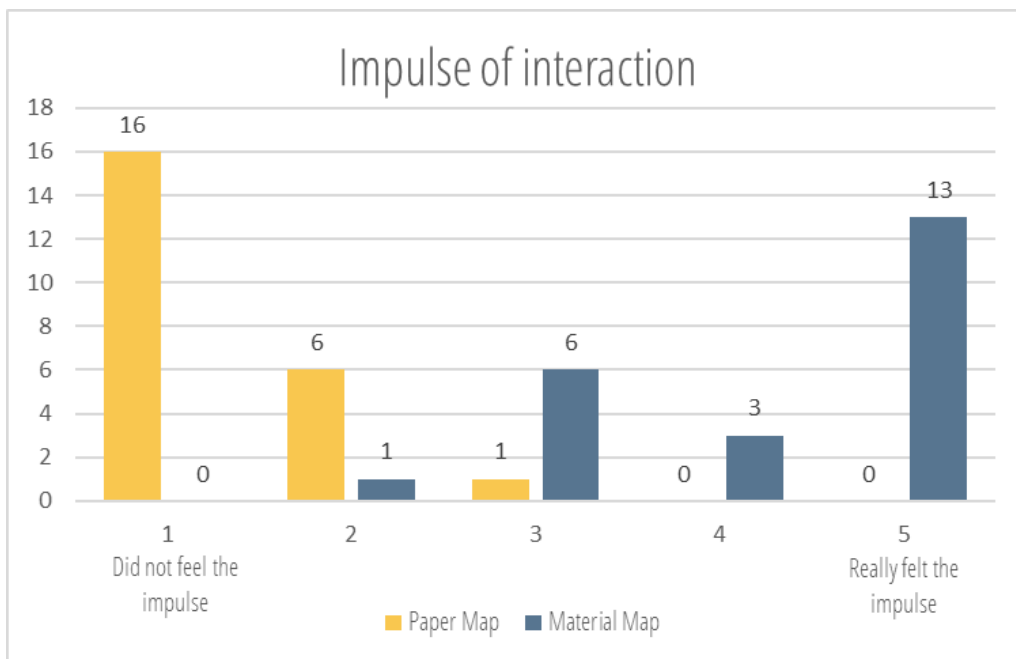


FIGURE A.14: Bar Chart 2

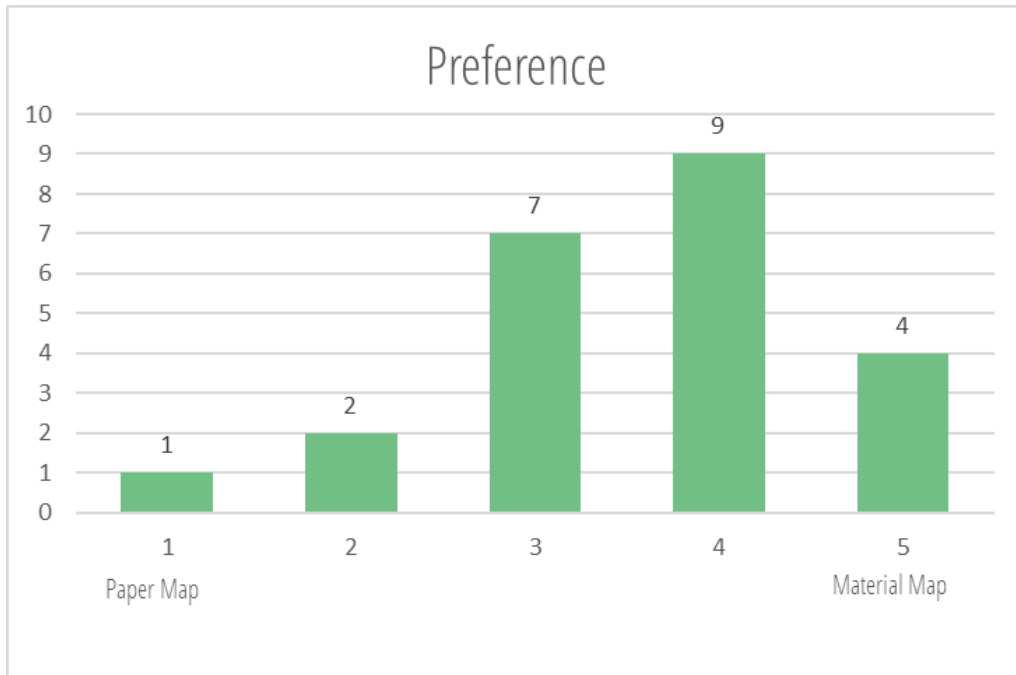


FIGURE A.15: Bar Chart 3

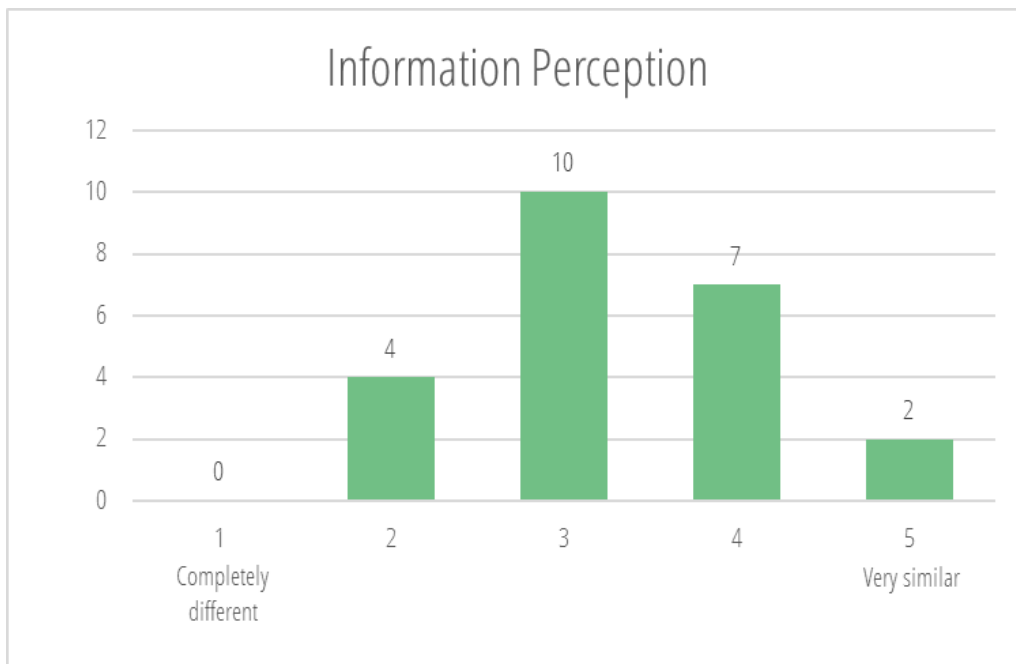


FIGURE A.16: Bar Chart 4

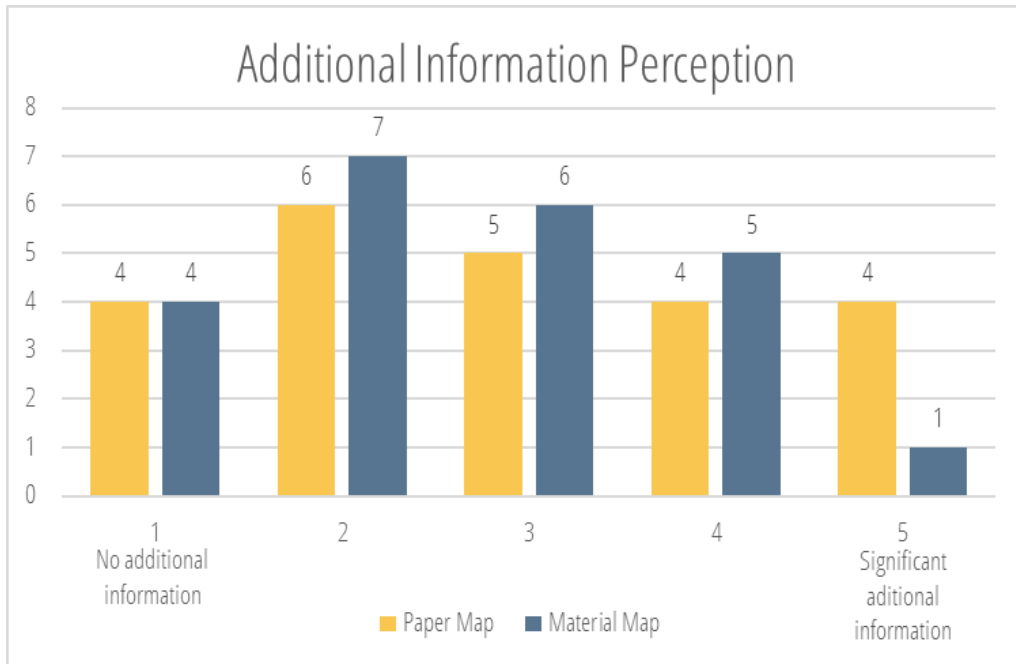


FIGURE A.17: Bar Chart 5

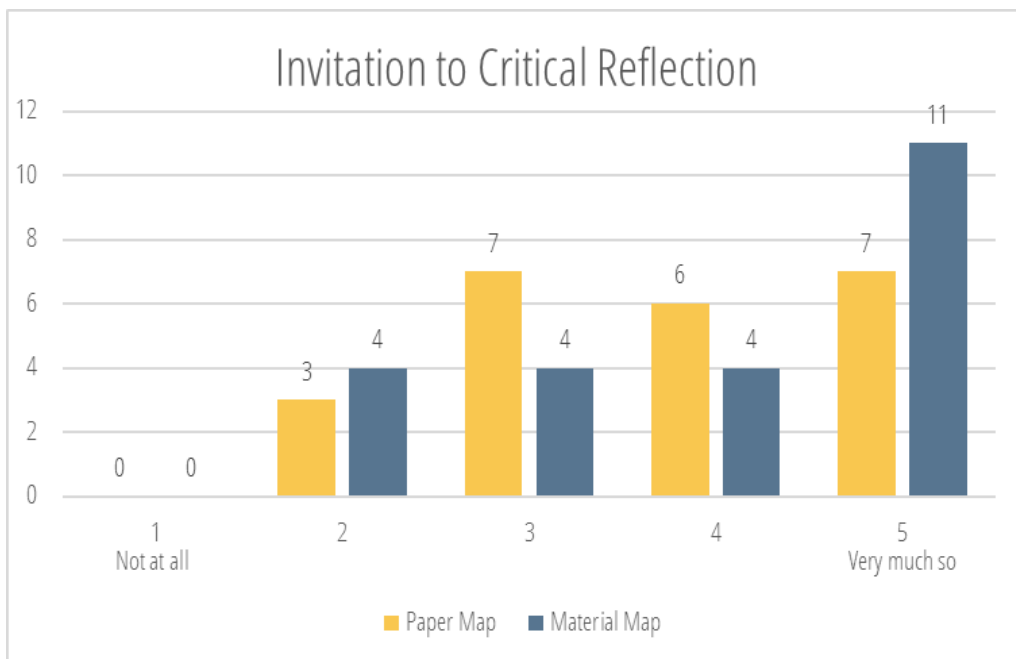


FIGURE A.18: Bar Chart 6

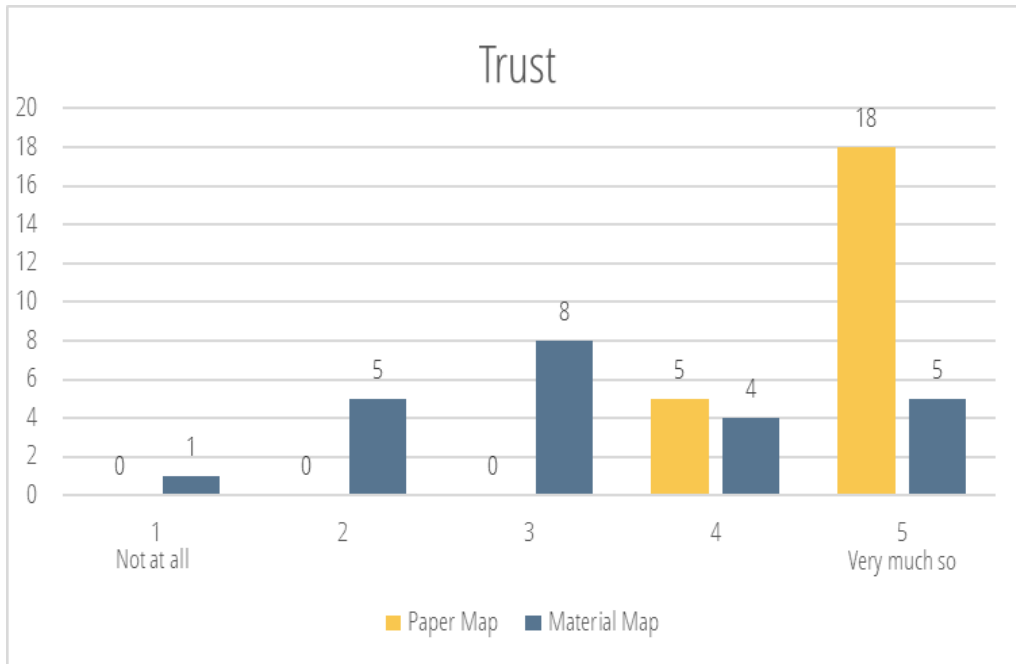


FIGURE A.19: Bar Chart 7

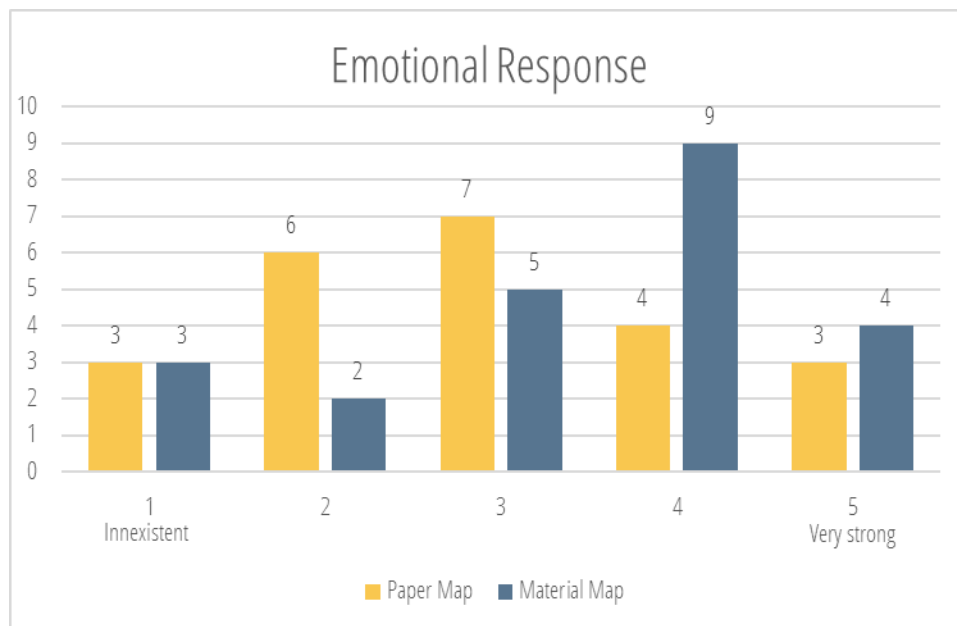


FIGURE A.20: Bar Chart 8

A.3 Statistical Analysis

```
QR=Results2$Q1.Paper.object
QT=Results2$i..Marca.temporalR=Results2$Q1.Paper.object
QT=Results2$i..Marca.temporal

#To what degree do you perceive the following object as a map?
PQ1=Results$Q1.Paper.object
MQ1=Results$Q1.Coins.and.bones.object
PQ1
MQ1

#To what extend did you feel the impulse to interact with the maps
#in ways beyond observing them, such as touching, smelling,
#or exploring them with your senses?
PQ2=Results$Q2.Paper.Map
MQ2=Results$Q2.Material.Map
PQ2
MQ2

#Did you feel more drawn to a map in particular?
Q3=Results[,6]
Q3

#Did you feel both maps conveyed similar information?
Q4=Results[,7]
Q4

#Do these maps convey additional information beyond what
#is listed on the legend?
PQ5=Results$Q5.Paper.Map
MQ5=Results$Q5.Material.Map
PQ5
MQ5

#How much do these maps involve you in a critical reflection
#about the topic presented?
PQ6=Results$Q6.Paper.Map
MQ6=Results$Q6.Material.Map
PQ6
MQ6

#How much do you trust these maps?
PQ7=Results$Q7.Paper.Map
MQ7=Results$Q7.Material.Map
PQ7
MQ7

#How strong is your emotional response to these maps
#(e.g. happiness, sadness, fear, anger, surprise or disgust)?
PQ8=Results$Q8.Paper.Map
MQ8=Results$Q8.Material.Map
PQ8
MQ8
```

FIGURE A.21: Quantitative data

```

#Shapiro Test to check Normal distribution
shapiro.test(PQ1) #p-value = 3.995e-10
shapiro.test(MQ1) #p-value = 0.0001676

shapiro.test(PQ2) #p-value = 2.099e-06
shapiro.test(MQ2) #p-value = 4.985e-05

shapiro.test(PQ5) #p-value = 0.02875
shapiro.test(MQ5) #p-value = 0.05137 ---- Normally distributed

shapiro.test(PQ6) #p-value = 0.005368
shapiro.test(MQ6) #p-value = 0.0002235

shapiro.test(PQ7) #p-value = 1.124e-07
shapiro.test(MQ7) #p-value = 0.029

shapiro.test(PQ8) #p-value = 0.06631
shapiro.test(MQ8) #p-value = 0.007803

```

FIGURE A.22: Shapiro test to discard normal distribution

```

#Descriptive Statistics (Mean and Median)
#Indicator of variability (Standard deviation)
#Non parametric test
#Wilcoxon Signed-Rank Test
#Paired

# Null Hypothesis: The median difference between pairs of observations is zero
#----> The perception of both Maps is similar

# Alternate Hypothesis: The median difference between pairs of observations is not zero
#----> The perception of both Maps is different

# Alpha = 0.05

# If p-value<0.05 ---- Null Hypothesis is rejected. The difference is statistically
#significant.

wilcox.test(PQ1,MQ1,paired = TRUE)
median(PQ1)
median(MQ1)
#data: PQ1 and MQ1
#V = 55, p-value = 0.004995
#AH ---- The perception of both Maps is different
sd(PQ1)
sd(MQ1)

wilcox.test(PQ2,MQ2,paired = TRUE)
median(PQ2)
median(MQ2)
#data: PQ2 and MQ2
#V = 0, p-value = 2.311e-05
#NH is rejected therefore AH ---- The perception of both Maps is different
sd(PQ2)
sd(MQ2)

median(Q3)
sd(Q3)

median(Q4)
sd(Q4)

```

FIGURE A.23: Wilcoxon Test for distribution comparison

```

wilcox.test(PQ5,MQ5,paired = TRUE)
#data: PQ5 and MQ5
#V = 113.5, p-value = 0.4635
#NH can not be rejected
median(PQ5)
median(MQ5)
sd(PQ5)
sd(MQ5)

wilcox.test(PQ6,MQ6,paired = TRUE)
#data: PQ6 and MQ6
#V = 82.5, p-value = 0.6218
#NH can not be rejected
median(PQ6)
median(MQ6)
sd(PQ6)
sd(MQ6)

wilcox.test(PQ7,MQ7,paired = TRUE)
#data: PQ7 and MQ7
#V = 153, p-value = 0.0002422
#NH is rejected therefore AH ---- The perception of both Maps is different
median(PQ7)
median(MQ7)
sd(PQ7)
sd(MQ7)

wilcox.test(PQ8,MQ8,paired = TRUE)
#data: PQ8 and MQ8
#V = 73, p-value = 0.2319
#NH can not be rejected
median(PQ8)
median(MQ8)
sd(PQ8)
sd(MQ8)

```

FIGURE A.24: Wilcoxon Test for distribution comparison

A.4 Word clouds

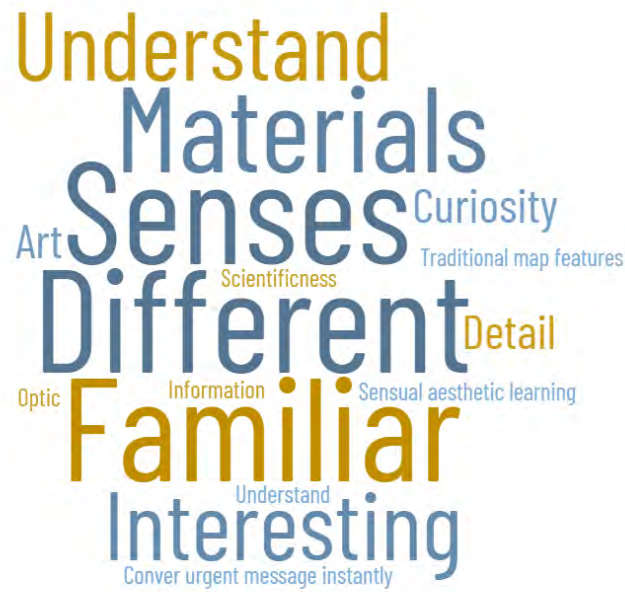


FIGURE A.25: Did you feel more drawn to a map in particular? Open answers



FIGURE A.26: Did you feel both maps conveyed similar information? Open answers



FIGURE A.27: Do these maps convey additional information beyond what is listed on the legend? Open answers



FIGURE A.28: How much do these maps involve you in a critical reflection about the topic presented? Open answers



FIGURE A.29: How much do you trust these maps? Open answers