UNIVERSAL DESIGN AND VISUAL IMPAIRMENT: TACTILE PRODUCTS FOR HERITAGE ACCESS

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ABSTRACT
This article presents a pilot study carried out in the city of Barcelona on assistive resources applied to an itinerary of possible interest to visually impaired people. The objective of this study was to use qualitative research techniques to analyze the use of tactile maps, produced with 3D printing, in order to allow people to identify and memorize routes. This analysis was carried out using an evaluation model based on the principles of Universal Design (UD). Four visually impaired users participated in this initial study. They tried the different mock-ups, providing an experience in response to the main research questions: “Could 3D printing be a good technique for making tactile maps for all users, especially visually impaired users?” and “Could a visually impaired person use a map printed with this technique to learn a route to visit an accessible heritage site?”

Keywords: Universal Design, mobility maps, visual impairment.

1 INTRODUCTION
The urban environment is a complex context full of difficulties for visually impaired people. These difficulties limit their possibilities in terms of mobility and access. They depend on their ability to memorize routes and to build cognitive maps of specific environments so that they can move around the city safely and independently. To aid them, there are some essential assistive devices such as white canes, GPS technology and audio information, as well as tactile devices.
Independent access to certain cultural contents such as patrimonial spaces and museums is a right, and also a necessary experience for blind and partially sighted people. Different cultural institutions are beginning to show a greater sensitivity towards this group by making some content accessible through tactile, auditory or olfactory resources.
The objective of this article is to evaluate an assistive device with inclusive design criteria. The product evaluated is a relief map for learning an urban route. The main users of these sorts of devices are blind and partially sighted people. The selected route is within the urban environment of a European city, Barcelona. See Section 4.2. This route was chosen because of the need of blind and partially sighted users to access and participate in cultural contexts.
The theoretical background of the products examined here is a multidisciplinary framework. Disciplines such as Geography, Perception Psychology or Education Sciences endeavour to improve these kinds of products to facilitate understanding and, therefore, to improve the quality of life of visually impaired users. In contrast, Product Design has not made a strong contribution in the field.

1.1 Tactile maps: Aim of this study
There are different types of tactile maps that are used to communicate and for learning geography or, also, for learning orientation skills in order to move through certain environments. These products can be classified according to Edman [1] as:
- Mobility Maps. These present information such as streets, buildings, obstacles, stairs, urban lifts, telephones, etc.
- Topological Maps. These present the itinerary to the blind and they have a high level of simplification and exclude external details.
- Orientation Maps. These contain less detailed information than Mobility maps, for example, transportation networks, shopping centres, recreational areas, etc.
- General Reference Maps, such as political maps or physical maps of a country.
- Thematic Maps. These present specific information such as population, climate, etc.

Normally blind individuals use these products before they follow a route to visit a new place. Generally, under the established protocol, the Mobility Instructors teach them the itinerary and then assist them as they try to follow the real route.
Studies show that visually impaired users prefer to consult these products at home to memorize the route before following it [2]. Once learned, they then need somebody to guide them on the real route. It should be noted that the utility of these types of devices to facilitate mobility, spatial orientation and the autonomy of visually impaired people has been shown in previous studies [3].
Finally, it is necessary to distinguish between tactile scale-models and tactile maps. Tactile scale-models represent real information in a volumetric format, whereas tactile maps represent the information encoded in symbolic elements such as points, lines and surfaces.

1.2 Production and design: new possibilities of 3D printing

The usual methods of production are thermoforming of plastic sheets and microencapsulated paper [4]. In regard to production it is important to note the great possibilities of the new 3D printing techniques. According to some studies, three-dimensional configurations can improve visually impaired people's understanding of these products [5].
Generally, in order to make this type of product easy to use and taking into account that tactile perception is not as sharp as visual perception, any tactile-graphic device must contain synthesized information in order to make it easily legible with the sense of touch.
If the tactile device contains corresponding visual information, adapted to the specific requirements of other groups, the number of users that may benefit will grow to include, for example, elderly or partially sighted persons, in harmony with the philosophy of Inclusive Design [6].
When learning a route, tactile information must be processed step by step, for example, first with a large-scale map (Orientation Map) that includes general information and then with another map that shows certain details on a smaller scale (Mobility Map). There are general requirements that must be mentioned now in order to highlight the particularity of the process of designing these products for the sense of touch. However, there are no set criteria and the general requirements greatly depend on the particular experience of each designer. The maximum size of any tangible graphic must be designed according to the space that the two hands can easily reach together. A comfortable hand position would include an area approximately the size of an A3 sheet, although maps may be bigger or smaller based on the different types of information to be represented. The distance separation between the elements represented, such as the symbols of a map, must be carefully designed. A minimum separation of 3 mm is needed between elements so they can be discriminated with the sense of touch. In any case, these data only represent a small part of all the requirements studied to design a correct tactile map. Extended and more detailed information can be found in reference publications [1] [2] [7].
However, most of the design guidelines published for relief maps are focused on the main methods of production. These production processes have some limitations in the reproduction of volumetric forms and are not so effective at presenting certain information expressed in the maps. The new techniques of rapid prototyping, such as stereolithography, selective laser sintering or 3D printing [8], allow this information to be represented with a greater volumetric complexity. Thus, this system of production expands the possibilities for improvement of tactile devices designed to aid visually impaired users.

1.3 State of the Art

There are previous studies related to this work, such as studies that analyze the value and importance of these kinds of representations in learning about particular places, and to facilitate the sense of orientation. These studies conclude that blind or partially sighted users improve their level of knowledge in the process of learning urban areas from even brief contact with these products. Also, the development of 3D printing techniques has led to other studies on how these resources facilitate the spatial orientation of visually impaired people in building environments. The work of Celani and Milan emphasizes that a group that especially benefited from the use of tactile models are users with low vision [9]. In this case, the tactile model was useful in building a mental image of the environment and establishing a relationship with physical references in the space. Finally, the work of Voženílek and colleagues also evaluates how these users interpret the space information in maps produced by 3D printing [10]. This study emphasizes the possibility of reducing the anxiety that independent travel causes the blind when they visit unknown places [11].

2 TACTILE MAPS AND UNIVERSAL DESIGN

Within the scope of Product Design, a trend that began in the USA aims to integrate the enormous diversity of users in the product conception. This is the well-known philosophy of Universal Design (UD) [12], also called Inclusive Design [6] or Design for All in other countries. The essence of this philosophy is centred on users with some type of disability, because if certain people with reduced abilities can use a product in optimal conditions of usability [13], then other users whose abilities are not reduced will be able to benefit from the product too.

In this sense, in terms of usability, it seems difficult to attend to all human needs and capacities. Therefore, it is necessary to create some criteria and principles to deal with the specific problems of how to create and evaluate products under usability parameters. The basic principles of UD were established by the Centre of Universal Design in 1997 and they are focused on the main aim of creating equality among people and improving the usability of products [12][14]. These principles are summarized in the following seven guidelines applicable to products, services and processes:

1. Universal and equitable use.
2. Flexible use.
3. Simple and intuitive use.
4. Easily perceptible information.
5. Design with tolerance for error, that is to say, the design must stand, among other factors, mistaken uses without affecting safety.
6. Design with requirements of low physical effort.
7. Design with enough space for access, accessibility, approach, maintenance and use.

Therefore, it seems appropriate to approach the design of tactile products focused on people with disability using the UD framework.

3 VISUALLY IMPAIRED USERS AND ACCESS TO CULTURE

It is important to keep in mind some information related to the individual profile of this type of user. Firstly, it is important to recognize that visually impaired people are a heterogeneous group and that knowledge of haptic reading strategies is fundamental for understanding these sorts of devices. This knowledge allows users to recognize, more accurately and effectively, the information offered in a tactile product, even in real contexts [15]. Secondly, the differences between congenital and non-congenital blindness determine the familiarization with these strategies of reading and the possibility of accessing visual memory, which is necessary for understanding graphical conventions. All of these factors determine the user's capacity to decode the tactile-graphic information and obtain correct knowledge of the environment, provided this information had been assimilated in an efficient way. In order to codify this information it is important to bear in mind several factors. Firstly, it is useful to combine verbal description with tactile exploration [3]. In this way, the data acquired from the sense of hearing can be complementary to the sense of touch, in any one of the possible formats of tangible graphics (tactile maps, scale models, tactile drawings, and so on), because the senses of touch and hearing are the means through which a blind person acquires most of their information. This last strategy improves the precise understanding of the environment represented in a map. A second aspect is to recognize the role of the haptic memory for blind people. A blind person explores the tactile graphics in a sequential way; in contrast, the phenomenon of visual perception is simultaneous and requires less time to assimilate the same information.

Some cultural institutions have already begun to integrate resources for users with visual impairment. For example, museums may show their temporary or permanent collections with inclusive criteria, offering audio-guides, scale models, fixed and permanent tactile maps of the premises, as well as a selection of pieces of their collections to explore with the sense of touch. The authors believe that the discipline of Product Design must help to overcome the challenge of making these groups of users regular participants in cultural events. In this sense, as a result of UD, visually impaired people would be able to enjoy and actively participate in heritage spaces, making it possible for them to participate in universal access to the knowledge contained there [16]. But, the first challenge is to improve independent travel to these places, especially in this group, who need help with visits.

4 METHODOLOGY

The methodology used in this study is based, fundamentally, on the use of ethnographic research techniques: in-depth structured interviews and direct observation. In addition, tasks with users and prototypes (mock-ups) and cognitive maps were carried out to evaluate the process of learning the environment [11][17][18]. The main problem in this study is reaching the amount of visually impaired people necessary to obtain quality data.

4.1 Evaluation Model

The evaluation model of the product used in this study, focused on the seven principles of UD [19].
In brief, the model has a first stage of analysis and a second stage of evaluation until the final product is obtained: that is to say, an acceptable object from the perspective of UD. The evaluation criteria are centred on the seven principles of UD, during the whole design process, so modifications can be required or made until the end of product development.

4.2 Product evaluated and scope of study.

The product evaluated in this study is a tactile map. It has been designed with volumetric attributes from a 3D scale model but, at the same time, it contains attributes from a typical 2D relief map. The device has been designed to be easy to use by the sense of touch and sight, but it is not a portable device and it has been designed for use at home [2]. See Section 4.4.
The map shows an area of the city of Barcelona, *Ciutat Vella* (the old town), and in particular the area where the old port buildings and the *Museu Marítim* (Maritime Museum) are located. This cultural institution is optimally equipped with resources designed for disabled people, particularly visually impaired people. These users could visit the museum in order to improve their social participation and knowledge of the cultural heritage of Catalonia. The proposed route shows the shortest access from the underground station exit to the Museum. This itinerary has two obstacles, a kiosk and a telephone booth. The users have to make two turns and they have to cross at two ordinary traffic lights. The route is approximately 100 m long [Figure 1].

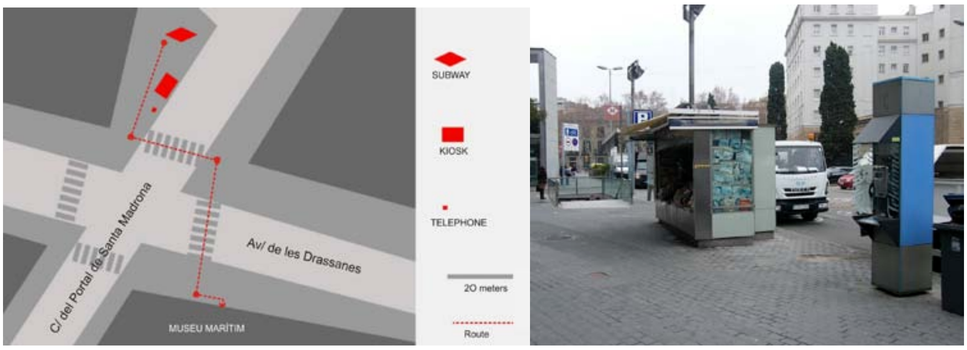

Figure 1. Route and obstacles

4.3 Sample and profile of the users

Four visually impaired users who were interested in the development of the tactile product participated in this study: three men and one woman. The range of ages of this sample are from 21 to 55 years old [Table 1].

Table 1. User profile

	Visual Impairment	Braille knowledge	Tactile map knowledge	Study area knowledge	Previous route knowledge
User A	Congenital/totally blind	Advanced	Advanced	Advanced	Poor
User B	Acquired/partially blind	None	None	None	None
User C	Acquired/totally blind	Advanced	Poor	None	None
User D	Acquired/totally blind	Poor	Average	Advanced	Poor

4.4 Material used in the study

Two types of relief maps were used: one Orientation Map and one Mobility Map. They showed the studied area with different scales. The design of the products followed Edman's recommendations [1]. The critical elements of these products can be reduced to: formal elements of representation; symbols; and Braille code and large text.

- Map 1. Orientation Map. This map was produced by milling rigid thermoplastic sheets. Scale 1:2800. Size 293 × 209 × 6 mm. The aim of this map was to help users locate the study area. It showed the synthesized information to help them understand the next map. Its design showed certain landmarks in the study area that the users would need to be familiarized with if they had no previous knowledge of the place. The landmarks were marked with Braille code for blind participants and large text for partially sighted participants. All the elements were designed with optimal colour contrast and relief. This map did not have a key in order to make it easier to use. All the necessary information was included in the map [Figure 2].
- Map 2. Mobility Map. 3D colour printing. Scale 1:1500. Size 200 × 188 × 34 mm. [Figure 2]. The objective of this map was to represent, in an extended way and with certain details, the study area in order to help the users memorize the proposed route. It had a separate key to 8 tactile symbols proposed by the researchers. The key contained descriptions of the 8 symbols in Braille and large text. The map showed most of the landmarks of the previous map and, also, pavements, buildings, crossings and a selection of street furniture, among other elements. All the elements were designed with optimal colour contrast and relief. This map would be evaluated later under the evaluation model proposed in Section 4.1 [19].

Figure 2. Map 1; Map 2 and key

- Map 3. Mobility Map. 3D colour printing. Scale 1:1250. Size 219 x 190 x 20 mm. This map was redesigned according to the results obtained from applying the proposed evaluation model [Figure 3].

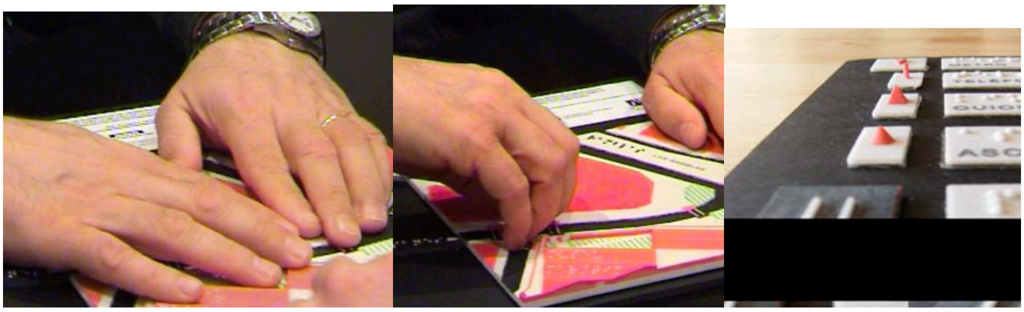

Figure 3. Map 3 and detail of the key

4.5 Plan of work and procedure

Stage 1. Usability test (Map 1 and 2). Firstly, with User A, the research team carried out four in-depth unstructured interviews, two of which took place while he tried the maps. The aim of these interviews was to obtain a first point of view from a blind user who was a specialist in the subject. He validated the material used and the tasks proposed in the study before the rest of the activities were begun with the other participants. This user tried all the material in a free and spontaneous way. The research team

observed his behaviour and tactile gestures, and wrote down his comments. User A did not participate in the other activities. The time spent on these activities with User A was approximately 240 min.
Second, users B and C both participated in a session of approximately 90 min each, divided into three fundamental parts:

- Part 1. Structured interview.
- Part 2. Prototype tasks and direct observation.
- Part 3. Cognitive map of the route learned.

Part 2 of each session was the most significant to the interests of this study. In Part 2, the participants interacted with the product, while they were observed and filmed.

Stage 2. Data Analysis. Usability evaluation. In this stage, the data obtained in Stage 1 was analyzed taking into account the evaluation model based on UD principles.

Stage 3. Redesign of Map 2 to produce Map 3. After analyzing the data collected in the first stage, the research team redesigned Map 2 to produce a new version of it. This new version was intended to solve the problems detected in the previous sessions with users B and C. The result of this stage was Map 3, which was obtained by applying the evaluation model.

Stage 4. Usability test (Maps 1 and 3). Finally, User D tried Map 3. The session was structured using the same protocol as in Stage 1, but its duration was slightly shorter than in the first stage with users B and C.

Stage 5. Data Analysis. Usability evaluation. In this stage, the data obtained in Stage 4 was analyzed under the evaluation model based on UD principles.

Stage 6. Results and conclusions. In this last stage the research team analyzed the activities from the perspective of the results obtained in the overall experience and then drew conclusions (See Section 6).

4.6 Experimental work

The three parts of Stages 1 and 4, Usability test, in which the users participated directly in the experience, were carried out as follows:

Part 1. The in-depth interviews in Stages 1 and 4 were divided into the following thematic blocks: Personal data; Interest in culture; Knowledge and experience of the urban environment; Knowledge of the use of assistive devices for orientation and mobility; and, Knowledge of the use of tactile products, especially maps for memorizing routes.

Part 2. Prototype tasks and direct observation. Firstly, the research team gave Map 1 to the participants and they described the type of information it represented, as well as the proposed route to memorize. On Map 1, the users had to identify the area in a general way.

Once the users were familiarized with the area with Map 1, the research team presented the key from Map 2 (in Stage 1) and from Map 3 (in Stage 4). No information was given about the content represented, or its visual or tactile characteristics. The users had to recognize each of the elements represented. The researchers asked them for a verbal description of the tactile symbol forms perceived using the sense of touch and also for the designations of the symbols represented in Braille code and large text (in the case of the low vision user). In this first task, the researchers measured the mistakes and the time taken to understand the key (Task 0).

Once the key had been presented and understood, the researchers gave the participants the next map, Map 2 in the case of Stage 1, and Map 3 in the case of Stage 4

The researchers briefly explained the map, then asked the users to verbally describe the different elements and the feeling of contact while they interacted with it. The users had unstructured contact with the map and the researchers interfered as little as possible in the activity, providing support by answering questions verbally. The degree of recognition of the different elements of the maps was observed. Then, the users were asked to try a new task (Task 1). In this task they had to identify some symbols on Map 2 in Stage 1, and on Map 3 in Stage 4. The subway symbol was used as the target symbol. The symbols were represented in the key and they were allowed to use the key if necessary. The discrimination of the symbols was observed and the time to locate and recognize the symbols on the map was measured.

Once the users understood the whole map, the research team asked them to try another task (Task 2), which consisted of following the itinerary (proposed by the researchers) with the fingertips and describing the elements detected along it.

Part 3. Cognitive map of the route learned. Finally, the users had to make a cognitive map of the route learned so the final task (Task 3) was to draw a sketch of the area. This activity assessed the understanding of the studied area and proposed route.

4.7 Record and reports

A record of all activities was made on videotape and a final summary report was produced for each user and each of the sessions. In addition, data were collected in situ.

5 EXPERIENCE AND RESULTS

Firstly, it is important to note that the participants were interested and motivated to assist in the development of tactile maps to improve their mobility and autonomy.

Stage 1 and 4, Part 1. Structured interview. From the interviews it is noteworthy that the four users needed to be helped by other people, such as Mobility Instructors, when visiting a new place, and they did not try to visit any unfamiliar place alone because they were afraid [4]. However, the daily route to their work or study site was carried out without problems. They said they would like to participate more in cultural activities. None of them used GPS technology, but they were habitual users of mobile phones with synthesized voice. They considered these sorts of devices and technologies very useful. All participants regularly used different types of products on a daily basis, for example, voice synthesizers, Braille devices, lens magnifiers, and so on. They valued all these devices very positively. User B had no experience in reading tactile maps. Users C and D had some experience using tactile graphics, but they did not have a systematic strategy of haptic reading. All of them considered these resources to be useful or very useful.

Stage 1, Part 2. Prototype tasks and direct observation. In Task 0, User B understood the whole set of symbols and large text on the key without difficulty. User C had, approximately, a 60% error rate in the description of the shape of symbols, although her descriptions were quite close to their formal attributes, for example she described the “U” shape from the subway symbol, as a “V”; or the three parallel lines from the crosswalk symbol as a rectangle with an interior line. In any case, she correctly discriminated the symbols, despite some doubts.

Map 2. User B did all the tasks proposed without remarkable difficulties and without verbal assistance. He said that he couldn’t use a regular paper tourist map and he liked the relief product with colour contrast and large text. In Task 1, User C identified the bigger symbols autonomously but, in general, needed verbal assistance to understand the elements she was touching on the map [3]. User C did Task 2 correctly. It is important to note the special use of fingers to touch the volumetric elements of the product: User C used her fingers as a clamp, see Figure 3.

Stage 1, Part 3. Cognitive map of the route learned. In Task 3, User B did this task with only one insignificant mistake. User C made a less accurate sketch, but with the information needed to correctly follow the route [Figure 4].

Stage 2. Data Analysis. Usability evaluation. After analyzing the first data under the evaluation model that includes the principles of UD the main problems detected were:

- Principle 3. The use of the product was not simple and intuitive for several reasons, one of which was that it became necessary for the researchers to intervene with some verbal explanations in order to help users understand all the information on the map [3].
- Principle 4. Some of the information presented was not perceived correctly. This aspect generated some confusion, and some information seemed unnecessary for understanding the route. The users asked for the names of some streets that did not appear on Map 2.
- Principle 7. Some parts of the model could not be accessed with the fingers, for example in some streets. Some elements of Braille were not detected because of their hidden position.

Stage 3. Redesign of Map 2: Map 3. The research team redesigned Map 2. The strategy used was firstly, to reduce the information presented to make it easier to understand the device, suppressing and simplifying the unnecessary items. The key was reduced to 6 items. Some shapes were simplified and 3D symbols of basic forms were used, such as the pyramid, thin cylinder and cone, which are easier to perceive with the “clamp gesture” of fingers than the previous flat shapes. In addition, the area represented was reduced and a larger scale was used in the new version. The dimensions of some streets and accesses were increased, taking into account anthropometric data [20], because they were not accessible with the fingers in Map 2. The street names that users asked for were added; these were not given in the previous version.

Moreover, the height of the confusing elements was adjusted, and the height of buildings was reduced to make it easier to access some parts of the map with the fingers.
Stage 4. Part 2. Usability test (Maps 1 and 3). User D had the following experience with the new design. In Task 0, this participant did not make any noteworthy mistakes in the interpretation of the symbols' shapes and he discriminated the key quite easily.
On Map 3, in Task 1, User D spontaneously found the lift symbol (cone) 6 seconds after interacting with the tactile device. This participant also found the kiosk (pyramid) without aid from the researchers. He took 35 seconds to locate the subway symbol and 26 seconds to locate the lift. This user even proposed alternative route to access the museum before carrying out task. User D needed less verbal aid. It is important to mention that this user oriented the map in a different way than that proposed by the researchers, which impeded his correct understanding of the Braille. User D did Task 2 correctly. On the other hand, he used his fingertips to find all the items presented without problems, and he used the "clamp gesture" to perceive the height dimension of the symbols in the same way as the other users [Figure 3]. The cone, cylinder and pyramid were felt because they pricked a little on the palm of the hands and so the participant found them quickly [Figure 3].
Stage 4. Part 3. Usability test (Map 1 and 3). User D did Task 3 correctly, sketching the route with its obstacles and turns [Figure 4].

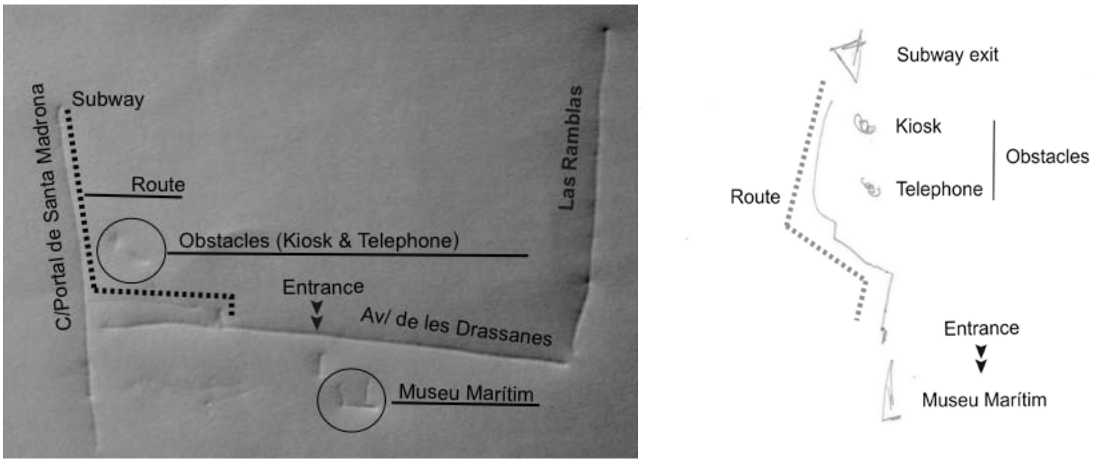

Figure 4. Cognitive maps sketched by users C and D

Stage 5. Data Analysis. Usability evaluation. The data collected in Stage 1, show that Map 3 is an improvement over Map 2. The tasks times were shorter and the information given was perceived with greater reliability. Nevertheless, the use of Map 3 was not completely autonomous because the user needed verbal information, as did the other blind users, and thus the map failed to fulfil Principle 3 of UD. The results of the tasks are summarized in Table 2.

Table 2. Results of the tasks (task times in minutes and seconds)

	User's profile	**Map**	**Task 0**	**Task 1**	**Task 2**	**Task 3**	**Map and route**
User A	Blind	User A tried all the maps in a free way					
User B	Low vision	Map 2	4:46	0:06	0:32	Correct	14:12
User C	Blind	Map 2	6:52	2:58	2:30	Correct	22:30
User D	Blind	Map 3	5:05	0:35	1:25	Correct	14:57

6 CONCLUSIONS

There were some weaknesses in this study in terms of the findings. This is a pilot study, so it has a small user group, although qualitative research techniques were used to try to obtain more in-depth information.
This article gives a brief example of a design process of a tactile model evaluated under the principles of UD [6][12][14][19]. This product can facilitate the learning of specific areas and, in a particular application such as the one presented here, it can assist in autonomous visits to cultural heritage sites that may be of interest to this group. It is essential to establish design guidelines to facilitate the successful creation of these products in three dimensions because the current ones were designed,

overall, to be used with thermoform and microencapsulated methods of production [4], both of a two-dimensional nature. The field of ergonomics and anthropometry could be useful because of the knowledge generated in its theoretical framework [20].
In the experimental part of this study, the positive data obtained in the cognitive map task (Task 3), shows the usefulness of these products as a tool for learning environments and urban routes for users who are blind and partially blind, as other studies have shown [3]. This may help to reduce the anxiety and fear experienced by visually impaired users when they have to follow a new itinerary in the city [11]. It should also be noted that the group of users with low vision may particularly benefit from this type of product as outlined in other studies [9], because throughout the study, User B did not have any significant problems in performing the tasks and he responded very positively to the use of the device with colour contrast and large text. Thanks to all these facts, we can answer the second research question of this study. Thus relief maps can be a complement to mobility in the city and particularly useful tools for accessing cultural institutions.
Through direct observation the researchers detected some gestures by users that are the potential basis of new resources for design to facilitate understanding through the sense of touch. The strategy of using several fingers, like a clamp, to perceive the dimension of height when processing the elevated symbols, the thin cylinder, the cone and the pyramid, allows a greater precision in the way of discriminating elements touched by hands [5] than employing the usual method of moving the fingertips on flat shapes. Moreover, the fact that these forms were even detected spontaneously through the effect of a pointed object touching the palm of the hands, allows them to be put to a new use as easily detectable specific elements. For example, point symbols of the map, which could be distinguished, given their high contrast, from flat symbols.
In general, the evaluation model allowed us to systematically analyze the critical elements of the product (Map 2). This made it possible to detect a variety of problems, which were later addressed with several design strategies. The result was positive because the time spent on tasks was reduced with the new design (Map 3). But even after reducing the time spent, the product needs to be redesigned again. The lack of autonomy in its use is a problem that should be taken into account in future redesigns. Verbal aid is still very necessary to understand tactile maps. It is important to substitute this function with other interactive systems. The challenge is to obtain efficient products with 100% of autonomous use. Further studies should work on improving the interactivity of these devices, using, for example, technological aids such as touch-sensitive surfaces that can produce spoken output or with GPS or Geospatial Information System (GIS) technology. Furthermore, this subject should be studied with a global perspective, beyond the methodology of user-centred design and paying attention to aspects such as sustainability and wealth, among others, in harmony with an ecodesign philosophy [21].
Finally, from all of the above, conclusions can be drawn about the first main research question: 3D printing could be a useful technique for making tactile maps and with this technique and verbal aid, the users were able to learn a route for visiting an accessible heritage site. Furthermore, the volumetric forms extend the possibilities of design for the sense of touch.

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