

# Slave Voyages: Reflections on Data Sculptures

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**Abstract**—This pictorial presents the development of a data sculpture, followed by our reflections inspired by Research through Design (RtD) and Dahlstedt’s process-based model of artistic creativity. We use the notion of negotiation between concept and material representation to reflect on the ideation, design process, production, and the exhibition of “Slave Voyages” — a set of data sculptures that depicts slave traffic from Africa to the American continent. The work was initially produced as an assignment on physicalization for the Design course at the Federal University of Rio de Janeiro. Our aim is to open discussion on material representation and negotiation in the creative process of data physicalization.

■ **SINCE ARISTOTLE, THE** history of Western thought has followed a hylomorphic model of creation, in which an agent with a particular design in mind imposes form to the material. Thus, the matter is rendered passive and becomes a result of what was forced upon it.<sup>1</sup> This model is still applied in art and design education. Moreover, in most design practices, the

configuration of an artifact is supposed to follow a blueprint that began in the mind of the creator.

Unlike the model for the blueprint in the artist’s mind, we see the creative process as a tension, a bouncing between concepts and the materials.<sup>2</sup> The artist’s intention could be compared to a seed, which changes as soon as they begin engaging with the availability of materials, tools, financial resources, feasibility, and the environment. Thus, iterated dialogues occur between head and hand.<sup>3</sup> Artistic and design creativity is a gradual and iterative process that involves the implementation of the idea or

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**Figure 1.** View of the data sculpture in the gallery of the Paço Imperial, Rio de Janeiro.

39 concept in a material form, followed by cycles of  
40 reconceptualization and refinement, until the  
41 material representation is considered “just  
42 right.”<sup>2</sup> Thus, the production of any artifact is  
43 much closer to a negotiation,<sup>4, 5</sup> in which the out-  
44 come or product is not a result of a perfect plan.

45 The classic visualization reference model  
46 describes three processes on how to create visu-  
47 alizations. In this model, the raw data are trans-  
48 formed into data tables, which are mapped into  
49 visual structures. Through user interactions, the  
50 visual structures are rendered and displayed.<sup>6</sup>  
51 Data transformation and mapping are also pro-  
52 cesses used in physicalization. Furthermore,  
53 both data visualization and physicalization are  
54 determined by the choice of tools and materials  
55 adopted. While the former requires frequent  
56 innovation and algorithm development, the lat-  
57 ter can make use of a variety of materials, which  
58 calls for various tools, some of them even  
59 archaic. In this context, the negotiation that hap-  
60 pens during a physicalization process can be  
61 more visible. Thus, the analysis of a physicaliza-  
62 tion design can be of great help in understanding  
63 the negotiation in the creative process.

64 In this pictorial, we explore the notion of  
65 negotiation in physicalization design, going back  
66 and forth between concepts and material repre-  
67 sentation. Based on Research through Design  
68 (RtD)<sup>7</sup> and on Dahlstedt’s model of artistic crea-  
69 tivity,<sup>2</sup> we reflect upon the development of a  
70 data sculpture, “Slave Voyages” (see Figure 1), a  
71 set of physical visualizations produced for a  
72 data physicalization assignment in the Visual  
73 Communication Design program of the School of  
74 Fine Arts, at the Federal University of Rio de  
75 Janeiro in Brazil. We describe its ideation, design  
76 process, production, and exhibition. We discuss  
77 the design uncertainty, positive points, prob-  
78 lems, and the role of materials and tools in the  
79 process, together with reflections on the negoti-  
80 ation in the creative process. We hope to pro-  
81 vide new reflections on the design and  
82 enjoyment of physical visualization, thereby  
83 opening up a discussion on material representa-  
84 tion in the creative process.

85 Research and Creativity in Design

86 In this pictorial, we applied RtD concepts  
87 mixed with Dahlstedt’s process-based spatial

88 model of artistic creativity.<sup>2</sup> RtD first appeared  
89 in Frayling's discussion on types of design  
90 research.<sup>7</sup> Its main goal is not the artifact but the  
91 knowledge and understanding produced in the  
92 design process. RtD can be applied in the con-  
93 text of a design project, led by a researcher who  
94 is also a practitioner-designer.<sup>8</sup> It is considered  
95 inseparable from the design experiment that  
96 interacts with reality<sup>9</sup> and is aligned to a relativ-  
97 ist perspective of research, which also considers  
98 intuition, interests, experiences, and values, and  
99 is increasingly acknowledged within the field of  
100 visualization.<sup>10</sup>

101 In the context of RtD, the concept of  
102 "annotated portfolio" offers a mode for organizing  
103 the knowledge produced during a design project.  
104 Annotated portfolios navigate between descrip-  
105 tive (related to the description of past occur-  
106 rences) and generative-inspirational (vision of  
107 future possibilities) modes, offering the research  
108 a way of reaching out beyond the particular,<sup>11</sup>  
109 bringing communicability and transferability to  
110 the findings from RtD. Both the annotated portfo-  
111 lio and the pictorial have a shared emphasis on  
112 the image in the production of knowledge. In RtD,  
113 all information gathered in the design process is  
114 considered valuable and should be collected and  
115 organized for further reflection. Thus, in this pres-  
116 ent study, field notes, sketches, cell phone photo-  
117 graphs, notes from discussions with colleagues,  
118 observations on intuition and coincidences expe-  
119 rienced, exploratory image searches via the inter-  
120 net, and difficulties that were either mastered or  
121 not, were reflexively documented as part of the  
122 design process.

123 The process-based spatial model of artistic  
124 creativity is a theoretical construction that pro-  
125 vided terminology and an apparatus for the  
126 reflections developed in this study.<sup>2</sup> It offers an  
127 explanation on how the creative process works  
128 as an iterative bounce between concepts and  
129 materialization, or between the idea and its  
130 reverberation over a material space. It presents  
131 how the artist's idea changes according to many  
132 things; for example, the material and tools avail-  
133 able, the knowledge of them, preferences, world-  
134 view, intuitions, and coincidences, among other  
135 things. Thus, this model provides value for the  
136 many details described in the design process of  
137 the data sculpture.

## Negotiation in the Design Process

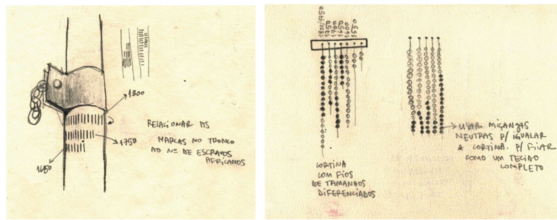
138 Physicalization is to encode data on a physi-  
139 cal shape through its geometry or material prop-  
140 erties.<sup>12</sup> In this context, the design of  
141 physicalization requires special attention to  
142 materials and tools. From the user perspective,  
143 physicalization provides the use of multisensory  
144 perception beyond the visual.<sup>12</sup> It can support  
145 active perception, because it allows exploration  
146 through movement around the object as well as  
147 near or far approaches. Designers and artists  
148 have been creating data sculptures to communi-  
149 cate meaning and provoke reflections.<sup>13, 14</sup>

150 This study started as an assignment in a  
151 physicalization course of the Design program in  
152 the School of Fine Arts, at the Federal University  
153 of Rio de Janeiro, Brazil. All students were infor-  
154 mation visualization novices, and it was their  
155 first experience with physical material for visual-  
156 izing information. Graphic software is normally  
157 their main tool. Professor Doris Kosminsky, the  
158 first author of this article, was the class instruc-  
159 tor, and Douglas Thomaz de Oliveira was the stu-  
160 dent who created "Slave Voyages." Before  
161 moving into the Design field, Douglas completed  
162 an undergraduate degree in History. He is still a  
163 high school history teacher and follows What-  
164 sApp groups discussing Brazilian history. His  
165 previous knowledge and interests drew him  
166 toward historical data, like those used in this  
167 project.

168 The creative process and production of the  
169 sculpture were discussed in class. Consequently,  
170 we considered the physicalization produced,  
171 and the reflections that followed, to be a product  
172 of collective knowledge developed in the class-  
173 room by the students and teachers. Thus, the  
174 description presented will use the pronoun  
175 "we," except in the cases where the explanation  
176 is only related to the student.

177 Following the classic reference model for  
178 visualization,<sup>6</sup> the students searched for data  
179 related to a theme of interest to them. As a histo-  
180 rian, Douglas was engaged with the slavery histo-  
181 ry in Brazil and already knew of the database  
182 available at the Slave Voyages website. The data-  
183 set is the result of international researchers'  
184 contributions, which began in the late 1960s. It  
185 shows 36 000 voyages between 1514 and 1866,  
186 which transported approximately 12.5 million  
187





**Figure 2.** A whipping post with marks representing data (left) and a curtain of beads representing data (right).

slaves. The sources used in the dataset were numerous and reliable. Sixty percent of these voyages have three or more sources confirming them. The Slave Voyages website offers more details on the data-gathering methodology. Although the dataset includes some slave ship arrivals in Europe, for the physicalization of Slave Voyages, we only considered the arrivals in the Americas.

### Visual Inspiration

Our design process began with a search for a shape or artifact on which the data could be mapped. Visualization practitioners usually initiate the design process with well-known visualization types, like charts, diagrams, or maps. However, in physicalization, the choices are greater but less known, given that mapping can incorporate a variety of shapes and materials. Based on the model of artistic creativity,<sup>2</sup> we consider that whatever choice is taken first, it will integrate a conceptual network that will move us forward until we find the best physicalization format. In this case, the visual choice is only a starting point.

We searched for visual elements related to slavery and African cultures, which could inspire symbols for the physicalization design. Our first ideas were related to instruments used to punish the slaves physically; for example, whips, pillories, or whipping posts (see Figure 2, left). We subsequently realized that the use of torture instruments would emphasize the brutality and injustice of slavery, but would not easily generate empathy or engagement. We wanted to create an inspiring physicalization that would contribute to understanding the history of modern African slavery. We believed that if the physicalization was aesthetically pleasing, it could

lead to more engagement. From our view, it sounds contradictory to attempt to create beauty from torture instruments.

While searching the internet for images, we found pictures of bead necklaces, which remind us of the ritualistic beads used in Brazil by followers of the African-based faiths. They believe that the bead necklaces help the spiritual connection between Orishas and humans. In other words, they represent the link between matter and the divine. Both the color and the number of beads in a necklace have a spiritual significance. In physicalization, standard beads represent locations on a map<sup>15</sup> and values in polls.<sup>16</sup> In artworks by data artist Loren Madsen, each bead represents a year, and their size is proportional to the number of terrorist-caused deaths for that year.<sup>17, 18</sup> We considered it appropriate to use beads in the physicalization of Slave Voyages because of their versatility. They are sold in many colors, which can represent different categories that can easily be counted. On the other hand, some historian friends who joined Douglas in a WhatsApp group questioned the use of colored beads to represent such a sad and vile event of humankind. In the end, we stuck to our decision regarding the beads.

Following this resolution, we were confronted with another design decision, which was the form of the physicalization using the beads. We first imagined a curtain of beads (see Figure 2, right), which was later dismissed. Since bead curtains are common objects, usually seen in homes, we realized they would not have an impact as sculpture, and so we continued experimenting with other forms.

Resuming the search for images, we got the idea of displaying the beads in circles or rings. A ring is a circle, a geometric shape with extensive meaning. It represents totality, timelessness, and cyclic movement— notions that intersect with history. We quickly made a first prototype to check the material's possibilities. We strung the beads on a thread and fixed them onto a circular iron ring. In the end, we decided to keep the ring shape but to string the beads through an iron wire.

### Mapping the Data

Once we decided to use the rings of beads in the physicalization, we were faced with two

Row: 50-year periods | Column: Specific regions of disembarkation | Cell: Sum of disembarked slaves | Omit Empty? This will eliminate empty results in the table.

Showing 1 to 8 of 8 entries

Year Range	Europe					Mainland North America				
	Spain %	Portugal %	England %	France %	Netherlands %	Rhode Island %	New Hampshire %	Massachusetts %	Connecticut %	New York %
1501-1550	166	298	0	0	0	0	0	0	0	0
1551-1600	0	58	0	0	130	0	0	0	0	0
1601-1650	287	77	0	0	0	0	0	0	0	0
1651-1700	1,615	42	0	308	0	47	0	70	0	1,499
1701-1750	1,205	2,388	0	3	0	646	0	1,647	126	2,127
1751-1800	0	1,024	15	0	0	1,727	15	750	148	3,583
1801-1850	0	0	0	0	0	158	0	0	0	0
1851-1900	0	0	0	0	0	0	0	0	0	0
Totals	3,273	3,887	15	311	130	2,578	15	2,467	274	7,209

**Figure 3.** The Slave Voyages website, with choices for year range.

275 other decisions: the value attributed to each  
 276 bead, and the period of time represented by  
 277 each ring. The Slave Voyages website displays  
 278 the sum of embarked and disembarked slaves  
 279 in ranges of 5, 10, 25, 50, and 100 years (see  
 280 Figure 3). We experimented equating each single  
 281 bead to 1000, 5000, and 10 000 people. We  
 282 tested many combinations, using each one in a  
 283 spreadsheet. Considering a ratio of 1000 people  
 284 for each bead in a 50-year-period, the biggest  
 285 ring (1751–1800) would require 3933 beads and  
 286 would be approximately 10 meters in diameter.  
 287 Such a huge ring would require thicker iron  
 288 wire in order to remain stiff and stable, and  
 289 would also require beads with bigger holes for  
 290 the wire to pass through, and so on. And there  
 291 is also the impossibility of transporting and  
 292 exhibiting the sculpture in a show.

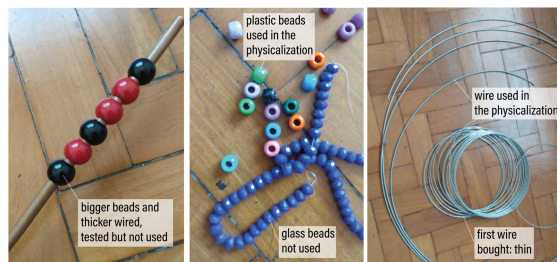
293 In the conceptual space, ratios such as 1000  
 294 people per bead would offer a better visualiza-  
 295 tion; however, in terms of material representa-  
 296 tion, this is not always possible. Besides this, we  
 297 were limited by the availability of standard materials.  
 298 Given these limitations, we decided to  
 299 maintain the ratio of 10 000 people represented  
 300 by one bead. We arranged the beads on the  
 301 rings, with each ring representing 50 years. We  
 302 had to round values in accordance with the  
 303 ratio. Sometimes we rounded up to include a  
 304 bead that otherwise would not have material-  
 305 ized. Hence, in this study, we see how materials  
 306 impose constraints on design, affecting the pro-  
 307 cess and the artifact produced.

308 From the values in the spreadsheet, we calcu-  
 309 lated the number of beads required. However,  
 310 we had to return to the store three times to pur-  
 311 chase more beads and twice for the wire. The  
 312 first beads bought were made from glass and  
 313 were very attractive, but we had to change to

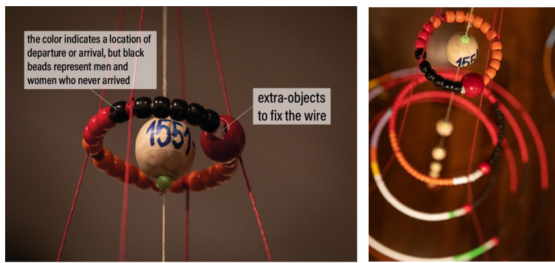
plastic beads, due to limited financial resources.  
 We made small prototypes using three different  
 wire thicknesses (see Figure 4). The first wire  
 bought was thin and limp and was sold in small  
 rolls, which would present challenges, due to  
 the rings' diameters. For instance, the smallest  
 ring, which was responsible for securing the  
 whole structure, would not be strong enough to  
 bear the weight of the other rings.

We also did not have the tools to weld or  
 curve the wire. The School of Fine Arts' workshop  
 only has a small rolling machine, so we contacted  
 professional blacksmiths. Given the time  
 involved, the need for precision, and what they  
 could charge, they were unable to accept the  
 order. The thicker wire also presented chal-  
 lenges. Although we had access to a professional  
 rolling machine, the diameter did not match the  
 specified size. We ended up using an 8-mm-thick  
 wire and 10-mm beads. The solution for fixing  
 the two ends of the wire was to use a new object  
 (see Figure 5). It is worth highlighting that we  
 did not have a proper studio to assemble the  
 pieces.

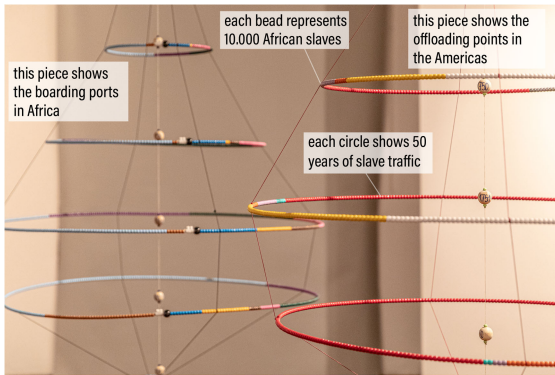
We produced two pieces (see Figure 6): one  
 for the outbound ports in Africa, and the second  
 for the inbound ports in the Americas (North  
 and South America as well as the Caribbean). We



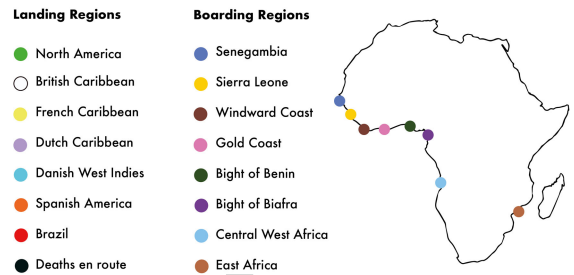
**Figure 4.** Prototypes for testing the beads and iron wires.



**Figure 5.** The object that fixes the wire in the ring.



**Figure 6.** Two pieces representing boarding and offloading ports.



**Figure 7.** Legend showing boarding and offloading ports.



**Figure 8.** Black beads, which represent the dead in the journey, were first placed following the beads for the port of arrival (see the sketch). Later, they were placed together in the ring.

used 2482 beads in the two pieces. Each piece had seven rings, distributed from top to bottom, which corresponds to the passage of time, beginning from 1551 to 1600. The largest ring, which shows the most intense period of traffic, had a diameter of 93 centimeters; while the smallest was 5.6 centimeters in diameter. There was no ring for the period before 1550, as we disregarded the data for this period.

The colors represent different ports or regions (see Figure 7) and were chosen from the available beads found in the market. The sequence of locations followed the order of the spreadsheet. The colors to represent each location were randomly selected, with some adjustments to avoid similar colors ending up side by side. Black beads were chosen to represent men and women who died on the journey. We initially tried to place the black beads following the beads for each port of arrival. We then realized that it was difficult to know if the black beads were related to the color group before or after them. For this reason, all the black beads were placed together on the ring, which would have more impact on the observers (see Figure 8).

In the first piece produced (see Figure 10), we have varied the space between the rings. Our idea was to reinforce the rising and decreasing of the slave traffic with the curves of the threads. However, this space did not reinforce the desired meaning.

We had difficulty transporting the pieces, because the wires tangled when not stretched tightly (see Figure 9). Because of this, only one piece was presented completed in class. We also encountered other constraints in the classroom; for example, it was not possible to hang the piece from the ceiling to have a preview of how it would fit in the exhibition. Although the participation of other students with suggestions



**Figure 9.** Sculpture not mounted.





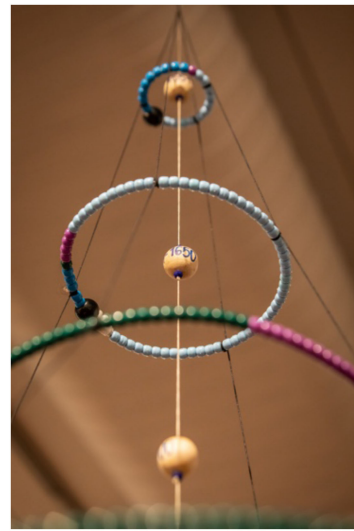
**Figure 10.** Douglas holding the sculpture.

382 regarding the design process was positive, the  
 383 development of the sculpture suffered due to  
 384 the time constraints inherent to any course.

#### 385 Exhibition and Further Development

386 From all the works created as assignments  
 387 for the course, “Slave Voyages” was the only one  
 388 chosen to be exhibited. The physical visualiza-  
 389 tion was shown twice, in two different collective  
 390 exhibits, both of them in Rio de Janeiro. The first  
 391 one was as part of a contest for the 7th Biennial  
 392 of the School of Fine Arts of the Federal Univer-  
 393 sity of Rio de Janeiro, between September 12  
 394 and October 13, 2019, at the Paço Imperial. The  
 395 second exhibit, “The sense of form: Design as a  
 396 poetic act,” took place between November 14  
 397 and December 13, at the Centro Cultural da  
 398 Light. It included works from students and teach-  
 399 ers of graduate programs in Design from around  
 400 Brazil. Both venues are famous cultural centers  
 401 in Rio de Janeiro.

402 Following the jury selection, we had to make  
 403 some improvements to the data sculpture to  
 404 guarantee its durability in the gallery for a whole  
 405 month. Given that the rings were not stand-alone  
 406 objects, we had to determine how they would be  
 407 displayed together. Alternatively, we tried to  
 408 arrange the rings perpendicular to the floor, but



**Figure 11.** Indication of the 50-year range.

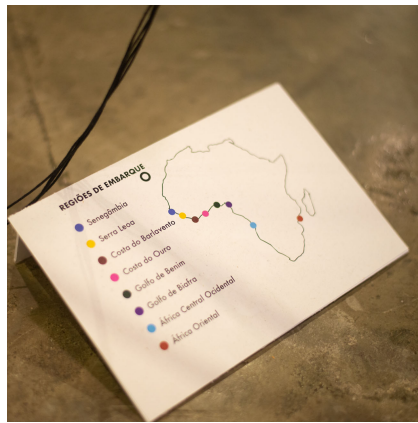


**Figure 12.** Indication of the 50-year range.

this configuration did not work, as it would  
 require a laborious binding system using two  
 opposite walls, which would require rigid spec-  
 ificities within an exhibition space. On the other  
 hand, once the sculpture is hanging from the  
 ceiling, it uses its own weight to stabilize itself.

The two pieces of the sculpture were linked  
 by threads, which represent the current relation-  
 ship between the two continents. The thread  
 was a last-minute idea during the assembly of  
 the sculpture in the gallery at the first exhibition.  
 Another idea implemented only in the exhibition  
 was the wooden beads to indicate the 50-year  
 ranges (see Figures 11 and 12).

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**Figure 13.** Color legend on the floor.

423 A complete understanding of the data of the  
424 visualization was only possible if the visitor was  
425 willing to examine the color legend placed on the  
426 floor beside the sculptures (see Figure 13), which  
427 explains the association between the colors,  
428 regions, and the ratio of 10 000 people per bead.  
429 Sadly, we observed that not everyone read the leg-  
430 end. We thought that the positioning of the legend,  
431 below the artwork, did not help. We later realized  
432 that the visitors' attention to this detail would  
433 have been better if the labels had been placed next  
434 to the beads' rings. Ultimately, we decided to keep  
435 the sculptures and legends as originally placed.

436 Although we did not test the understanding  
437 of the data used in the physicalization, we took  
438 some time to observe the visitors and talked to a  
439 few of them. Many visitors perceived the pat-  
440 terns highlighted by the physicalization.  
441 Through the diameter of the rings, they men-  
442 tioned the massive number of slaves transported  
443 on the voyages, many of whom died. They also  
444 observed the prevalence of specific colors. For  
445 example, red represented Brazil, which was the  
446 last country to end slavery and the destination  
447 of 40% of those arriving in the Americas. One vis-  
448 itor commented that the work was ethereal,  
449 referring to the lightness of the sculpture. An  
450 elderly Afro-Brazilian watchman at the Paço  
451 Imperial's cultural center could not hide the  
452 emotion the work aroused in him.

453 One of the most relevant aspects of the exhi-  
454 bition was the opportunity to enjoy the physical-  
455 ization in an appropriate space. Both exhibits  
456 offered great opportunities to observe the public



**Figure 14.** View of "Slave Voyages" at the gallery of Paço Imperial, during the 7th Biennial of the School of Fine Arts.

457 reaction, in addition to raising questions not  
458 elaborated during the production process; for  
459 example, the relationship of the physicalization  
460 with the surrounding space.

461 As one can see from the images, the data  
462 sculptures have spatial volume but little density.  
463 All the materials used (e.g., beads, threads, and  
464 wires) were light and thin, with a low physical  
465 embodiment. Although the beads were numerous,  
466 their arrangement did not guarantee immediate  
467 visibility. Taking photographs of the artwork was  
468 not a simple task, because it blended with the  
469 other objects in the exhibition as well as the back-  
470 ground (see Figures 14 and 15). During the design  
471 stage, we did not pay attention to the importance  
472 of the surrounding space for more profound vis-  
473 itor engagement with the physicalization. That was  
474 a mistake.

475 The design of a data sculpture was an excel-  
476 lent opportunity to observe the negotiation  
477 between the material and the environment. The  
478 materialization of the slavery data had an appeal-  
479 ing outcome, but not without pain. Lots of negoti-  
480 ation between the original idea and the material  
481 had occurred during the assemblage process.

482 Although the data presented reflects an  
483 extremely violent historical process, marked by  
484 cruelty and indifference to human life, we never  
485 intended to present graphic violence. We aimed  
486 to attract the attention of the visitors toward the  
487 work through its aesthetic and artistic aspects  
488 and to suggest a delayed more in-depth engage-  
489 ment with the physicalization. Thus, we think  
490 that our intention was achieved.





**Figure 15.** View of “Slave Voyages” at the gallery of Centro Cultural da Light.

After the exhibition, we sent some pictures of the data sculpture to researchers from the Slave Voyages website, and we received a message from its co-manager, who is a professor of African History. He told us that glass beads had an important role in the slave traffic trade. We were totally surprised by this information but it helped us to understand the concepts of intuition<sup>10</sup> and coincidence,<sup>2</sup> which have become more frequent in design research studies.

## CONCLUSION

In this study, we discussed the design and exhibition of data physicalization associated with Atlantic slavery traffic, based on RtD and on the model of artistic creativity.

The two exhibits offered an opportunity for an unstructured observation of both the artworks in the gallery, and the visitors’ perception of the historical information represented in the sculptures. Although not new, the use of beads in the physicalization reinforced the poetic aspect of the artwork amid the violence of the history represented in the data, which made the pieces more attractive.

By describing the iteration in the creative process involving the design concept and the material representation, we intended to present the design as a process that involves negotiation. We also aimed to highlight the agency of

external subjects in the outcome of the physicalization; for example, the difficulties in transporting the artwork, the space surrounding the artifact, and other external constraints.

The knowledge generated from the design of the data sculpture and the posterior reflection about it surpasses the description of the configuration for a generative-inspirational vision. It includes the hit-and-miss that constitutes the creative process, in general, and the physicalization design in particular.

We think that physicalization and data visualization designers could benefit from integrating the subjective perspective offered by the materials and tools, as well as external factors, into the creative process.

As a takeaway, we suggest that designers pay more attention to the negotiation between concept and material representation in its multiple possibilities. We also hope that this pictorial stimulates alternative approaches to future physicalization projects.

## ACKNOWLEDGMENTS

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