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Jun 25th, 9:00 AM

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Citation

Abbate, L., and Marino, C. (2022) Designing data interaction in exhibitions contexts, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), *DRS2022: Bilbao*, 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.693

DRS 2022
Bilbao 25th June — 3rd July

Design Research Society

Designing data interaction in exhibitions contexts

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https://doi.org/10.21606/drs.2022.693

Abstract: Nowadays, the primary purpose of information representation is to support users in understanding complex phenomena. Avoiding the 'black hole between data and knowledge" means research tools and methods that help people experience and benefit from this data. Through the analysis of case studies, the contribution aims to provide an overview of existing data visualization and physicalization techniques that enable participatory processes with users. This contribution focuses on interactive data visualizations, particularly on installations in museums, exhibitions or events that involve the user in an active and participatory way. These types of activities offer a simple but effective way to make complex data understandable. It will explore processes of collaborative creation of input from visitors, processes of direct interaction of the public with data that are not easily accessible by traditional methods, and finally, some visualizations that, through this powerful representational medium, promote renewed needs for engagement.

Keywords: data visualization; data physicalization exhibition; interaction design

1. Introduction

Over the last decade, the data revolution has attempted to change the way we live progressively, work and think, to improve our social, cultural, and economic condition. A phenomenon that has become increasingly all-encompassing, driven by big data infrastructures, which have seen the birth of several neologisms linked to its cultural dimension, such as datafication (Lycett, 2013), data-ism (Brooks, 2013), data revolution (Kitchin, 2014), dataveillance (Van Dijck, 2014), datafied society (Van Es & Schäfer, 2017).

The increasing digitization of information and relationships and the diffusion of data generated by things, people, and organizations represent both a challenge and an opportunity to design tools suitable for the complex and changing environment in which we live. Therefore, it is essential to understand how to extract maximum value from information, emphasizing

the communicative potential it contains (Mayer-Schönberger & Cukier, 2013). The real cultural and social challenge is to communicate, give meaning to the information collected and make it understandable to the most significant number of people (Manovich, 2011).

According to the Oxford English Dictionary, the term data visualization means, on the one hand, the ability to interpret information in visual terms by forming a mental image based on the data; on the other hand, the application of appropriate methods to put the data into a visible form. This, in turn, includes the action of visualization as a human cognitive activity whose result is the processing, encoding and transformation of quantitative, qualitative, relational and/or spatial information into visual material.

The discipline of data visualization is very complex by its interdisciplinary nature, precisely because it intends to communicate data and/or information through graphs and images to make them more understandable. The complexity of the discipline and the achievement of the problematic mission have also increased under the development and implementation of digital tools for the fruition of the same data; for instance, the evolution of digital devices has widened the means to represent and transmit knowledge, skills, and has made them available to a broad audience, think of RawGraph (Mauri et al., 2017), an open-source web app where data are entered and processed directly on the browser. Another push offered by digital technologies has been to broaden the focus of data visualization on how content is interacted with and enjoyed.

Initially exclusively informative, the purpose has also given way to a physical and material dimension to increase interaction and involvement with the audience. In this sense, data physicalization has provided further proof that it can activate participatory processes in understanding complex phenomena and immerse the user in different levels of involvement and interaction.

The museum world, taking early advantage of the experiential benefit that data visualization could bring, initially saw a growing number of artists using data as raw material for their artworks (Figure 1). Later, the emergence of this new opportunity saw the use of visualization as a means of expression and data physicalization as an approach to increase interaction and add quality to the user's experience of understanding information. In this context, the domain of pure information has invaded the world of interaction design and the material world to shape new visualization techniques capable of adding meaning and awareness to the user experience. Each visualization, or physicalization for that matter, can take the form of a different interface and potentially open a window onto a multitude of not only quantitative but also, and above all, qualitative data.

Data physicalisation can educate a broad audience such as museums and exhibitions, improve the efficiency of information retrieval and the memorability of data compared to similar designs shown only flatly and passively (Jansen et al., 2013).

This new form of knowledge fruition interprets the spirit of the digital age, just as the Bauhaus analyzed the logic of the industrial society, according to which "form follows function",

and although the purpose remains information, the methods used are entirely different, the visualization is brought into a public, collective, and often participatory space. In the museum context, it is not only about the representation of data but also about narration, which creates extraordinary narratives by linking to aesthetics in surprising interfaces. Therefore, the museum and the exhibitions, including temporary ones, represent a strategic point to inform and educate a broad audience about a process, that of data visualisation, which allows it to go out and be accessible not only to an expert audience anymore.

This paper, therefore, aims to define a set of best practices to improve the output of multidimensional data representation and the efficiency of the design process within the museum and exhibition context, through an analysis of case studies in the literature.

Figure 1 Giorgia Lupi Static data Visualization - Data Items: A Fashion Landscape 2017 - Commissioned for Items: Is Fashion Modern? This project made possible by Glasgow Caledonian New York College's Fair Fashion Center

2. Multimodal data interaction in exhibitions contexts

As data continues to grow at unprecedented rates, significant challenges arise in the search for new ways to visualize it (Del Favero et al., 2009).

Physical modelling of data offers the possibility to address and experience other dimensions, including tactile and material properties such as texture, weight, cultural meanings of materials, to make the user more aware of the enjoyment of content (Hanington & Martin, 2019). Data physicalization can take advantage of additional sensory channels to convey a broader range of meanings than a simple static and two-dimensional display (Jansen et al., 2015).

In this context of data representation, the aesthetic and expressive dimension plays a crucial role in the design. It is linked to the field of data visualization in the discipline of info-aesthetics, which in turn studies how the contemporary culture responds to the challenge of managing, storing, and circulating increasing amounts of data through the pursuit of communication strategies in fields ranging from design to architecture, from science to the design of human-computer interaction.

In this dimension, even natural objects, with all the effects they produce, serve what he calls Data Physicalization, a field in which "a physical artefact whose geometry or material properties encode data" (Jansen et al., 2015).

Through digital and physical data visualization, the viewer is asked to interact with DataViz by reorganizing search patterns and searching for features within paintings, works and scientific information, which allows them to connect not only with the artworks in a much more personal way and by becoming deeply familiar with the artist but also with cultural heritage in general and with specific knowledge. Furthermore, the correlation between digitization and physicalization of data in some areas brings a mutual benefit from a physical approach to observation and representation that mere digital models cannot get.

In some cases, the physicalization of data makes it more accessible and understandable and introduces new ways of thinking and leads to creating designs that can be uniquely tailored to the specific type of problems the visualization addresses.

Behind the use of these media for artistic purposes and within museum and exhibition contexts, two main visions coexist: the first one focuses on the use of personal data as an asset for corporations and government, as a means to increase engagement; while the second one exploits the poetics and rhetoric of data by appropriating a tool that usually erases the emotional side of inputs by turning them into numbers and, finally, reversing the traditional process by adding a human side to both inputs and outputs through the creation of accessible experiences.

In this contribution, we will explore collaborative creation processes of input from visitors, techniques of direct interaction of the public with data that are not easily accessible by traditional methods, and finally, some visualizations that promote their enjoyment through this powerful medium.

Today, users of museums and exhibitions find themselves interfacing with visualization techniques such as dynamic graphs, diagrams, maps, and large-scale tangible plots. These visualizations include varying degrees of interactivity and navigation: from static visualizations, where no interaction is possible, where one focuses on a specific story, told from a single point of view; to dynamic visualizations, where the user can perform different actions for the fruition of the data, with tools such as filtering and zooming (Figure 2). Interaction depends on several factors, such as the purpose of the data and the need to manage a certain complexity and amount of data. Managing these large data sets requires dynamic visualization, as it is impossible to display them all at once. Furthermore, it is evident that the user's role according to the chosen visualization changes; in static visualization, they are simply a user/viewer who merely observes, while in dynamic visualization, they are the protagonist of their own experience. By exploring different linked and in-depth datasets, users can find new meanings and apply them again, rather than using a static image or a guided video.

Interacting with the data visualization in many installations enhances user learning and attention through continuous visual and auditory stimulation. Dynamic visualizations can include on-demand labels, definitions and links to additional information or more complex graphics, with the ability to add user datasets. Indeed, studies have found that visitors find value in participating in creating data visualizations (Wojton et al., 2018).

In museum and exhibition contexts, to effectively implement constructivist learning experiences, visitors need to take the lead in exploring topics according to their interests. Still, they also need to be supported by new or unfamiliar ideas (Hohenstein & Moussouri, 2017).

Consider, for example, touch screen displays, which encourage visitors to participate in quick 'research' studies, recording their observations when required, and creating a simple graph of their data against a more extensive set of all visitor data, allowing individual users to have a personal experience with the collection and display of data. Thus, visitors become participants in the background: protagonists and recipients of the visualization.

Data visualizations, information, concepts, scientific ideas, data, or facts are abstracted for a broad and diverse audience. This leads to an interdisciplinary approach to creating a more understandable and tangible experience for the audience (Coghlan & Coughlan, 2014).

Figure 2 mARChive - Interface for Museum Victoria's collections that allows access to eighty thousand documents from the collection as an experience within a 360-degree three-dimensional screen - Dynamic Visualization, from https://www.jeffreyshawcompendium.com/portfolio/marchive/

3. Methodology

The study, which aims to contribute to this growing area of research by exploring the exhibition scenario, takes the form of a case-study analysis.

The area identified for the research gathers examples of case studies circumscribed within the museum and exhibition scenario without a categorization concerning the theme and objective of the representation. The selection criteria refer instead to the degree of transformation of information (see Figure 3). The case studies are thus classified according to four criteria:

- data input and visualization output

- modality of use of the information according to the analogue and digital variables.

The case studies that fall under the digital category, both in input and output, represent examples of experimentation where the data must be digitally transformed once received.

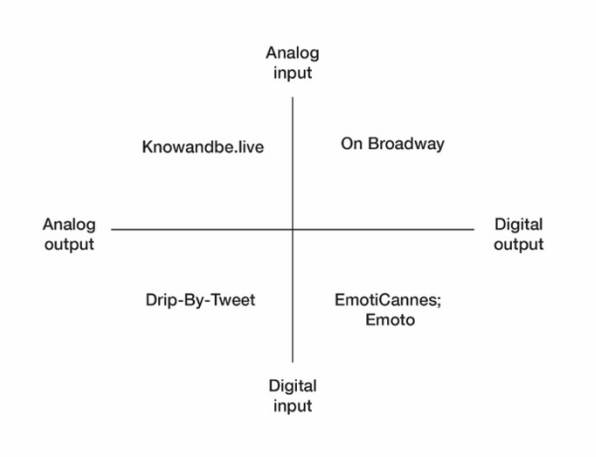

Fig 3 Summary scheme of the categorization of the case studies

Alternatively, analogue case studies are where the return of the value of what is being measured does not transform, and therefore, no further reading codes are required.

In both cases, however, interaction strategies were identified that qualified the user experience by enabling the observer to gain a deeper understanding of causes and effects that would otherwise be difficult to discern. For this reason, we then restricted the investigation to case studies in which the participatory visualization process was explicit to the user.

We used a case-study approach to determine the factors that affect the exhibition context in general and the role of the design visualization strategies to qualify the interactive experience.

The different degrees of the interaction of the participants, although variable, contribute to representing examples of how the museum reality has dealt with the themes of data visualisation in recent years. Furthermore, the selection of such case studies is intended to provide a meaningful framework of users' analogue or digital input modes intersected with the same display output modes (Figure 3).

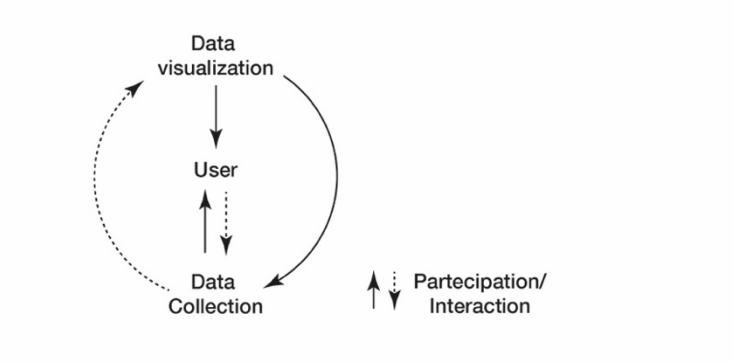

Figure 4 Interactions with data visualizations may involve several actions by the user. From the creation and implementation of the visualization with one's data to the simple use of packages already represented, but still navigable.

3.1 Case studies

Knowandbe.live: complex issues discussed with the user

The digital platform for cancer prevention education, Knowandbe.live, has been created to inform and raise awareness on cancer statistics and good prevention practices through a collaborative and participatory end-user approach.

In this context, the activity Participatory Diagrams (2019), performed in collaboration with the Visual Journalism Platform of the University of Bolzano, the leader in research on visual journalism, sought to make tangible and perceptible through different senses a delicate, sensitive topic such as cancer and the need for proper prevention (Moretti & Mattozzi, 2020). A multidisciplinary team, therefore, carried out the project made up of designers, sociologists, and cancer prevention experts, who brought in different skills (epidemiology, science dissemination, eLearning, storytelling, visual journalism, data design and video-making) to arrive at a final physical and participatory data visualization product.

The participatory experience (+ Knowledge - Fear) was realized through the development of two diagrams. The first consists of a panel presenting 12 questions that participants answer by knotting a thread to a series of knobs, creating a tangible data visualization (Figure 4). The data represented are mainly figures on cancer incidence and survival to encourage the audience to question commonplace assumptions. The questions divided into two groups were aimed at the participants' lifestyle (Figure 5) to familiarize them with the experience; then, the participant was asked to give numbers they did not know, prompting them to guess how many people see the data on cancer and making the participants aware of the information gap (Figure 6). This work aims to check the participants' level of information, make them aware of their information gap, arouse their curiosity about the correct information, and guide them towards learning.

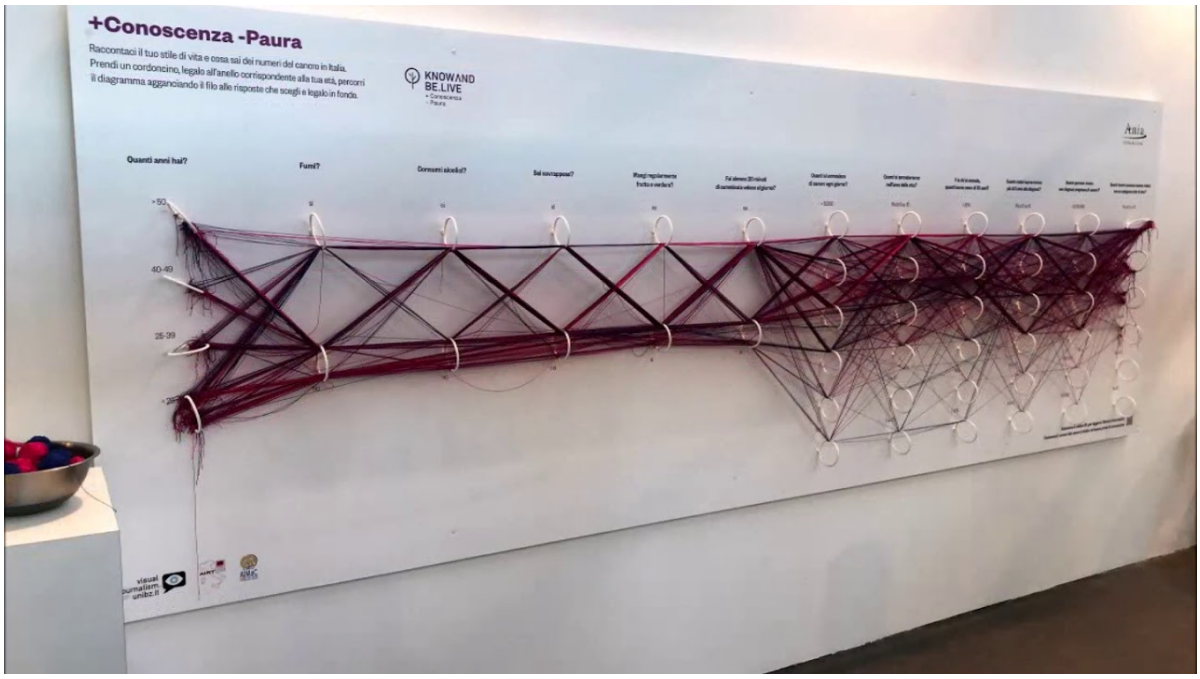

Figure 5 "Participatory Diagrams" Experience - Diagram 1 "+ Knowledge - Fear" created by Knowandbe.live and University of Bolzano, from https://knowandbe.live/it/index.html

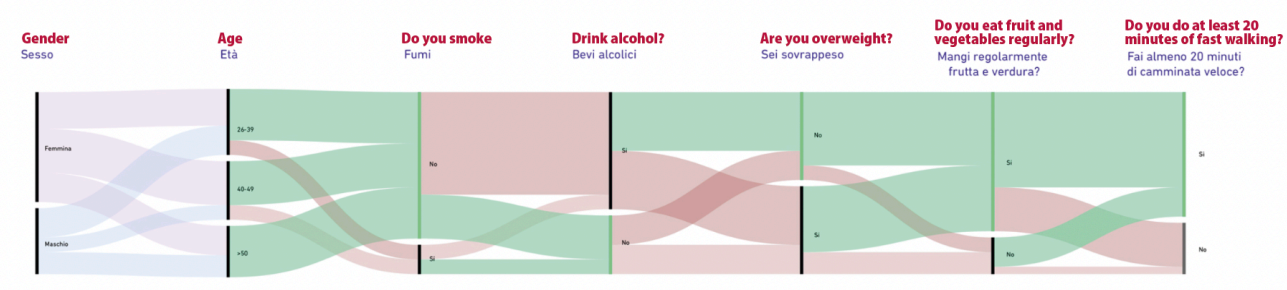

Figure 6 "Participatory Diagrams" Experience - Diagram 1 "+ Knowledge - Fear" First group of lifestyle questions created by Knowandbe.live and University of Bolzano, from https://knowandbe.live/it/index.html - in red the English translations of the questions in the graphs

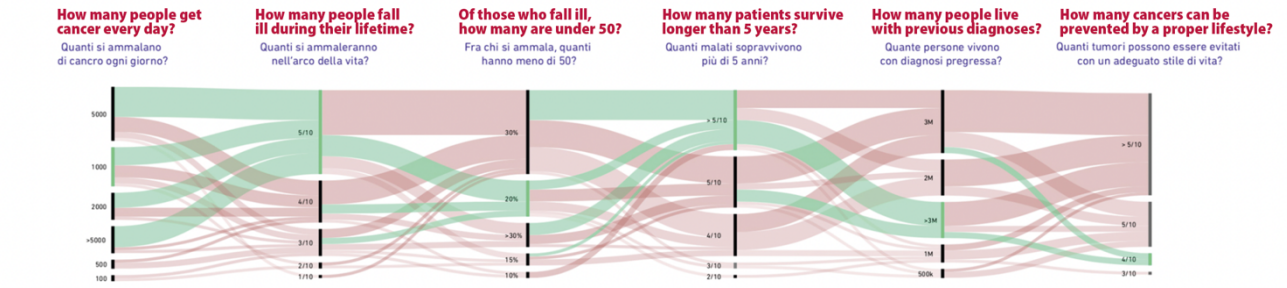

Figure 7 "Participatory Diagrams" Experience - Diagram 1 "+ Knowledge - Fear" Second group of questions on the information gap created by Knowandbe.live and University of Bolzano,

from https://knowandbe.live/it/index.html - in red the English translations of the questions in the graphs

The second diagram investigates the behavior of the participants on prevention, a vertical panel that asked only one question: "Which secondary prevention check-ups do you carry out?" Each participant answered by placing a colored token (blue for men and fuchsia for women) at the crossroads between their age group and the check-up they regularly carried out (Figure 7).

The significance of the visualization offers exciting insights into the lack of information and the importance of preventive controls.

"Participatory diagrams" attempt to use an active and experiential learning methodology through data visualization, which addresses the need to find new languages to significantly expand the culture of prevention and achieve a higher level of user awareness.

Figure 8 "Participatory Diagrams" Experience - Diagram 2 "+ Knowledge - Fear" Group of questions on the number of controls created by Knowandbe.live and University of Bolzano, from https://knowandbe.live/it/index.html - in red the English translations of the questions in the graphs

On Broadway a visual metaphor to represent the city

The interactive installation and application entitled On Broadway represent life in the 21st-century city through a collection of images and data taken along the 13 miles of Broadway stretching across Manhattan (Figure 8). The project was created by Daniel Goddemeyer,

Moritz Stefaner, Dominikus Baur and Lev Manovich as part of the exhibition Public Eye: 175 Years of Sharing Photography, which began in 2014 until 2016 and is on display at the New York Public Library.

The aim was to have a new vision of the city, created by the activities and media shared by hundreds of thousands of people. The project thus proposes a unique perspective and a set of insights for thinking about the city: a vertical stack of layers of images and data.

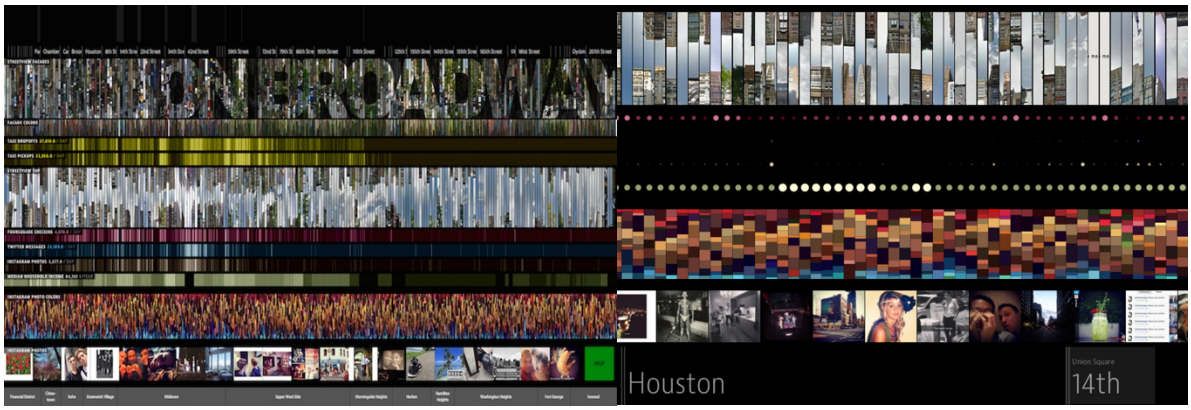

Figure 9 A close-up of the installation screen showing part of the Greenwich Village area - The view of 13 full miles of Broadway in Manhattan created by Niel Goddemeyer, Moritz Stefaner, Dominikus Baur, and Lev Manovich from http://www.on-broadway.nyc/

The project includes 13 of these layers, all aligned with places along Broadway. The images and data have 660,000 Instagram photos shared along Broadway during the six months of 2014, Twitter posts with images, Foursquare check-ins since 2009, Google Street View images, and 22 million taxi pick-ups and drop-offs in 2013, and economic indicators from the US Census Bureau (2013). Additional layers showing the names of Manhattan's Broadway neighborhoods, cross streets and landmarks have been added to aid navigation.

The collected data divide Broadway into two very different parts. The first part (which we will call 'Broadway 1'), shown in Figure 9, extends from the Financial District to 110th Street; the second part (which we will call 'Broadway 2') covers the region from 110th Street to the northern tip of Manhattan. Broadway 1 has much more social media activity, taxi rides and tourist photos than Broadway 2.

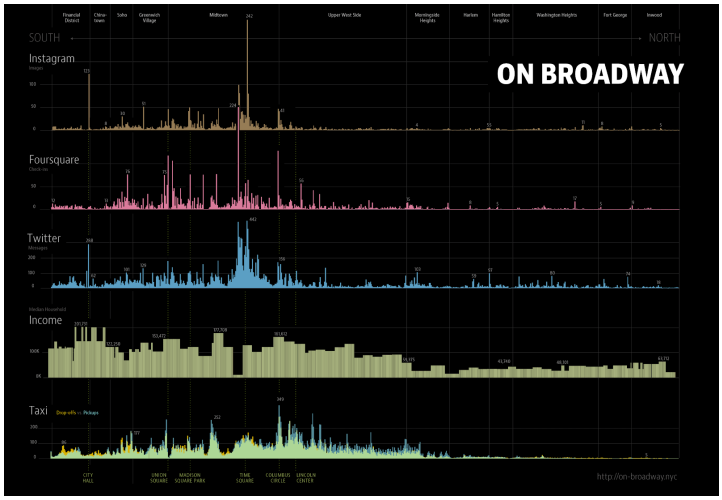

Figure 10 On Broadway Models and results created by Niel Goddemeyer, Moritz Stefaner, Dominikus Baur, and Lev Manovich from http://www.on-broadway.nyc/

An immersive installation where digital offers an interactive way to visualize and understand data. The user can actively and proactively browse through it and explore new city perspectives. A method in which the data archived over six months can offer the visitor material on which to reflect on the current state of things and how they might develop future perspectives, to live an experience that he can control and explore through his actions.

Drip-By-Tweet: a machine that makes the intangible tangible

The installation Drip-By-Tweet (2014) is an open system that aims to shed light on hidden processes such as the voting system, rethinking it through real and virtual relationships (Figure 10). Specifically, the visualization makes tangible the voting system behind the LAUS Audience Award, which is assigned every year to the most voted candidate in the FAD Awards of Design in Spain. The voting, which usually takes place on Twitter, collects preferences for nominees on social media, and the standard of participation is over 5,000 Tweets.

The LAUS Award organization wanted to increase participation by involving the design studio Domestic Data Streamer, which developed the Drip-By-Tweet installation to add value to the award. This artefact consists of a kinetic mechanism that transforms tweets/votes in real-time into a liquid infographic to move from the digital intangible to a meaningful physicalizing of data. So, for example, a person can vote by sending a tweet, after which the machine releases a drop of yellow liquid and sends it to the corresponding tube.

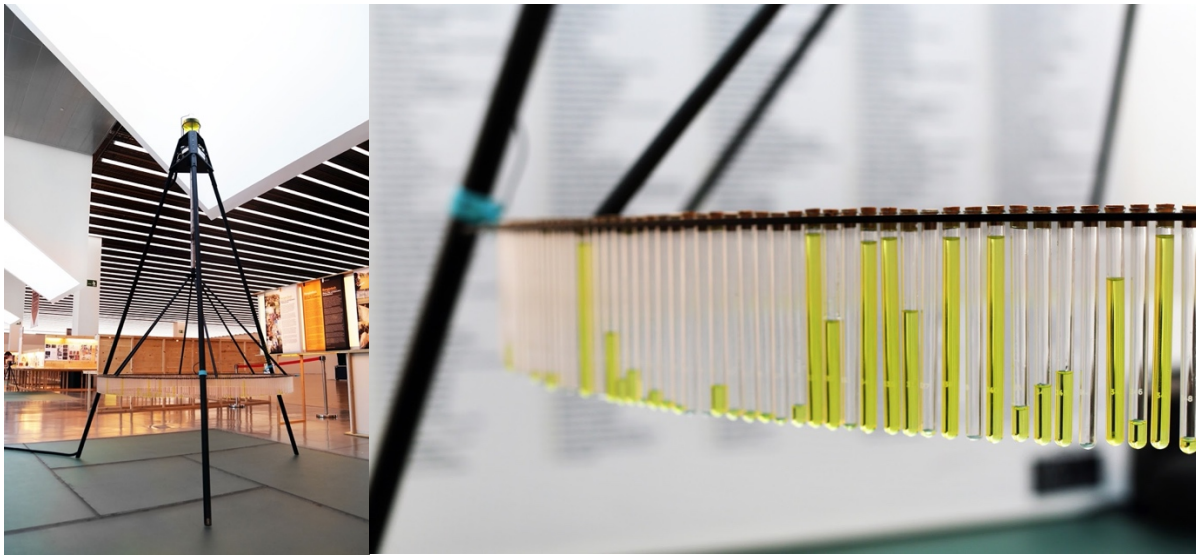

Figure 11 Drip-By-Tweet (2014) shows real-time physicalization created by Domestic Data Streamer. Images taken from https://domesticstreamers.com/projects/drip-by-tweet/

One of the visualizations of the most remarkable things that work in terms of meaning is the concept of transparency. The real-time interaction shows the voting process in progress and the contents of each test tube associated with the machine. Each of the 341 test tubes was linked to one of the candidates. As soon as someone voted by tweeting one of them, the device dropped the liquid into the specific test tube. The whole system changed the voting process and the prize itself. Each test tube was after the vote given to the candidates, turning into an award, no longer just one, but several with the proportion of the votes.

A participatory process where the user is called upon through their voting action to actively change the data visualization and obtain a greater awareness of what is going on in the winner's election.

EmotiCannes: a data visualization in emotional design

EmotiCannes is a visual artwork composed of 180 small screens which stream live data on the emotions of Cannes Festival attendees. Designed by Jason Bruges Studio in 2015 in collaboration with the sponsor of the Cannes Film Festival and the media planning agency MEC, the sculpture was created to give physical insight into the emotions of the Festival's spectators by obtaining information from social media (Figure 11). EmotiCannes can be considered a project of evolution of data visualization in experiential design. An experience in which the visualization changes in real-time allows the visitor to understand the speed and changeability of data acquisition. The changes thus lead the user to have a less reflective and more intuitive/emotional perspective.

A live emotion barometer, EmotiCannes, collected the social media activity of over 10,000 festival attendees, analyzed this massive amount of data and revealed it in real-time as meaningful insights into the prevailing mood of the festival crowd.

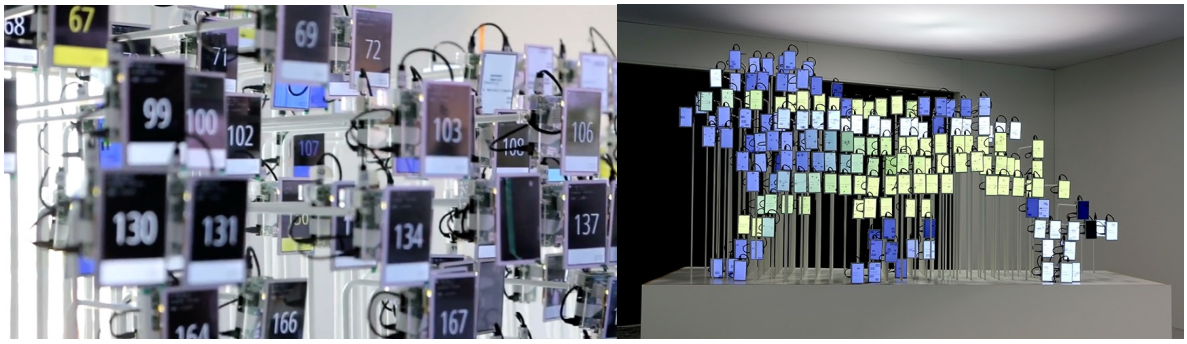

Figure 12 EmotiCannes interactive sculpture at Cannes Lions Innovation Festival created by Jason Bruges Studio from https://www.jasonbruges.com/emoticannes.

The installation collects tweets from across the Festival, each rated and weighted as a positive or negative sentiment. The physical data display changes color in response; these have informed other aspects, changing the flow. EmotiCannes is simultaneously sensitive to its viewers: sensors determine the viewer's position, gaze and reaction and add another layer of detailed data to the tweet and sculpture.

You can determine the peaks and troughs of the festival commentary and the highs and lows of people's emotions. You can then drill down into the information and see the individual tweets in the visual stream. The design challenge was to bring a considerable amount of data, which is usually only displayed on a few screens, to live and breathe in a physical space.

Emoto: a data sculpture for social sentiment in real time

Emoto is an installation created in 2012 for the London Olympic Games (Hemment, 2013) that captured and visualized the global response around the event on Twitter in an interactive online view and a sculpture of physical data (Figure 12). In this data art commission, the creative advantage was to produce a real-time visualization of social sentiment, a journalistic analysis of the games and a sculpture of physical data.

In this context, a type of graph called "sentigraph" was developed, which encodes the feeling in color and the vertical position of a line, and at the same time the number of messages in the strength of the line - it proved very effective. The custom infrastructure consumed the Twitter Streaming API, looking for tweets related to the Olympics and classifying them into sentiment categories (from "happy" to "angry" or "sad" messages). In addition, topics of interest such as disciplines, athletes, nationalities, etc., were found with a real-time sentiment profile for issues relevant to the games. These sentiment profiles were displayed based on a unique form of visualization, like origami, which allows easy comparison of how popular or controversial different topics were at a given time. In addition, incoming tweets were displayed in a stream-like message display, with a "reverse parallax effect", where the larger ("more important") tweets floated more slowly upwards, while those less mentioned or referred to tweets flew faster into the background.

A conceptual accompaniment to the activities on the web, a data sculpture has been created that has kept the more than 12 million tweets in physical form. With 17 CNC milled slabs - one for each day of the games - with an embossed thermal map indicating each day's emotional ups and downs. Overlapping projections highlight individual stories, and visitors could scroll through the most retweeted tweets per hour for each level using a control knob.

Figure 13 Emoto Data Analysis and Emoto Sculpture created by Moritz Stefaner, Drew Hemment, Studio NAND from https://truth-and-beauty.net/projects/emoto

4. Conclusion

The research for new ways to visualize data is essential for a world that produces and consumes digital data at unprecedented rates (Keim et al., 2006).

The most obvious result of this investigation is that it is possible to exploit the exhibition space to experiment with new ways of representing and enjoying data. Through analyzing case studies, classified according to the criteria of data collection and interaction, both analogue and digital, the contribution sought to offer an overview for the identification of best practices for the design of interactive and participatory data visualization systems.

One of the evidence from the case studies comes with the classification of analogue or digital inputs in the participatory process for users (Djavaherpour et al., 2021). Analogue data collection allows for greater participation because it is linked to users' personal data and manipulated or manipulable through physicalisation to increase collective awareness. At the same time, digital data collection through the process of data representation allows also collecting those intangible data that users are not aware of, such as emotions, making them visible and accessible.

Among the good practices identified, it emerges how in the relationship between exhibition realities and data visualization, a participatory approach can increase users' involvement, understanding and awareness of complex phenomena. Furthermore, in the analyzed visualizations, a multi-disciplinary approach is necessary, including social science, anthropology and psychology skills alongside design, computer, and communication engineering, given the

complex nature of multimodal data representation, to arrive at a product designed according to a Human-Centered Design (HCD) approach. Indeed, visualization systems are often designed for specific groups of users who have clear objectives and work in circumscribed environments (Wassink et al., 2009).

This also suggests that in the representation of data, the participatory mode allows the entire experience to be transformed from a mere visualization of quantitative data into qualitative emotions, feelings, and perceptions for users, which offers them greater transparency (Miller, 2019), even concerning the process of data representation itself (e.g., Drip-By-Tweet).

Visualization used as a vehicle for understanding complex data is a tool that can add meaning to the visitor experience, especially when there is a clear educational objective, as in the case of Knowandbe.live, and/or a solid narrative structure, as well as with On Broadway.

Another aspect that the designer must focus on designing a data physicalization for the museum context is the time frame of the data collection. On the one hand, if data is collected before the user experience, there will be less interaction participation and more reflexive involvement in the data physicalisation. The visitor, in this case, will be an active user in the access to the content (interaction, navigation and exploration) but passive in the data collection (before his visit). On the other hand, if data is collected in real-time, there is a more emotional approach triggered, for example, by the immediate change of the visualization. A process in which the visitor is a passive user in the use of the content but active in terms of the volume of data collected.

Ultimately, the results suggest that designing a multimodal data visualization is likely to increase user time spent on the site or interest in interacting with data visualizations both quantitatively and qualitatively.

Some of the emerging practices related to digital collections are increasingly prominent, partly due to the use and appeal of data visualizations themselves and partly due to the transformative power of the user experience.

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