

UNIVERSIDADE CATÓLICA PORTUGUESA

**COLLABORATIVE PROTOTYPING AND HACKING:
RE-INVENTING THE MUSEUM SPACE IN THE INFORMATION
TECHNOLOGY**

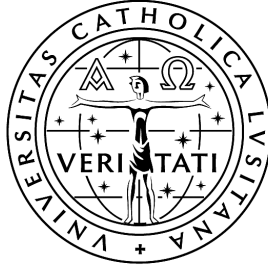
Thesis submitted to the Portuguese Catholic University for the Doctoral Degree in
Science and Technologies of the Arts

by

Gérald Vincent Estadieu

ESCOLA DAS ARTES

September 2019



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By Gérald Vincent Estadieu

Supervised by Prof. Doutor Carlos Sena Caires and

Co-Supervised by Prof. Doutor Álvaro Barbosa

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To Karine, Sarah, Danaël and Matthew

Abstract

Interactivity is a complex phenomenon to apprehend. Past researches have defined interactivity in contrasting terms: from a tautological expression of a computer-based system (Adams, 1999) to an independent system capable of intelligent dialogue (Smuts, 2009). We are presenting, based on the literature review, the spectrum of interactivity as a gradual complex system that can evolve in time.

The majority of interactive apparatuses evaluated in academic publications have all looked at the interactivity under the prism of the audience engagement. However, following authors such as Crawford and Weissberg, we are arguing that interactivity has its inherent properties, independently of the interactor and its environment.

The context of this research is specified in the first part of this thesis by introducing, not only the interactivity but also the museum as a public space in quest of interactivity and finally, the hacking methodology. This methodology is inspired by the hacking community and has evolved into a creative process. We are then running an experimental study mainly based on Museomix, the playground of our research, where collaborative prototyping and hacking are part of the core values for offering new mediation to museums.

This thesis presents the development of a holistic approach to understand and classify interactive apparatuses based solely on their properties; this has led us to propose a comprehensive framework to collect information from a large dataset of experimentations and to demonstrate the potential of this framework to provide a deeper understanding of the modes of interactivity and help us to classify them in our context of museology.

Resumo

A interatividade é um fenómeno complexo de apreender. Recentes investigações definiram a interatividade em termos contrastantes: desde uma expressão tautológica de um sistema baseado em computação (Adams, 1999), até um sistema independente capaz de um diálogo inteligente (Smuts, 2009). Apresentamos aqui, e com base na revisão da literatura, o espectro da interatividade enquanto um sistema gradual e complexo que pode evoluir no tempo. A maioria de aparatos interativos avaliados em publicações académicas olharam para a interatividade sob o prisma do envolvimento do seu público. No entanto, e no seguimento de autores como Crawford e Weissberg, defendemos que a interatividade tem propriedades intrínsecas, independentemente do interator e do seu envolvimento.

O contexto desta investigação está especificado na primeira parte da tese, através da introdução, não só do conceito de interatividade, mas também do museu enquanto espaço público à conquista da interatividade, e finalmente, da metodologia do hacker. Esta metodologia é inspirada na comunidade de hackers, que tem evoluído para um processo criativo. Realizamos posteriormente um estudo experimental, baseado essencialmente no *Museomix*, o campo da nossa investigação, onde a prototipagem colaborativa e o *hacking* fazem parte dos valores centrais que oferecem uma nova mediação para os museus.

Esta tese apresenta o desenvolvimento de uma abordagem holística para compreender e classificar aparatos interativos baseando-nos apenas nas suas propriedades intrínsecas; permitindo-nos assim apresentar uma estrutura compreensiva de recolha de dados de uma base alargada de experimentações e de demonstrar o potencial desta estrutura de análise afim de propor um entendimento mais aprofundado dos modos de interatividade e ajudar-nos a classificá-los no contexto museológico.

Acknowledgement

This thesis would not be possible without the support of my supervisor Professor Carlos Sena Caires and my co-supervisor Professor Álvaro Barbosa. I am grateful they both encouraged me to start this journey and continuously supported me to venture into the work I am presenting now. Although my background is in engineering, both at educational and professional levels, I was never fully satisfied with the technical side of my works, I knew I was missing something. It is very clear to me that without the encouragement of Professor Alvaro Barbosa I would not have found not have jump to find my path to creative industries. I want also to mention my friend Yves-Armel Martin, who co-founded Museomix and has always been an inspiration to me.

I owe an immense debt of gratitude to my colleague Filipa Martins de Abreu, my partner all along this journey. We have been working in parallel on our respective thesis, supporting each other to finally reach this moment, thank you! I am thankful to my colleagues from the Faculty of Creative Industries, specially to Daniel Farinha, Marco Leong and João Cordeiro for their continuous support and for believing in me, even when I did not.

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CHAPTER I

Introduction

1.1 Research motivation

Since the early age of humanity, artists, engineers and creative people have always been investigating and experimenting with technologies of their times. One of the most iconic examples was Leonardo Da Vinci in the XV century. An artist with a “feverishly inventive imagination” who kept experimenting to understand the unknowns of his time and create new apparatuses to answer scientific questions or resolve common problems of daily life. Always humans have invented and built machinery, more and more complex over time, in a quest for knowledge or out of curiosity. We also have been fascinated by those same machineries and apparatuses and keep discovering new ways of using them to our advantage.

Since the birth of modern computing systems after the Second World War, man has created a new environment: the digital world. Scarce at first, it is now a large part of our modern life where the physical and digital worlds are more and more intertwined to the point of where most of us cannot live without both.

Interactive technologies have, over the last forty years, changed the way man interacts with its digital environment but also with the real world. Technologies have had an impact on all aspects of human life. One can see on most of all objects in our daily environment how technologies have been integrated to make them “smart”, or at least to change their behaviour based on what can be understood of our own human needs. Many objects built today are embedded with technologies which are used to either amazed us - such as in art installations - facilitate our life or on some of the worst scenarios, control us as well.

Museums around the world have been facing challenges over the last few decades. In a world where technology penetrates everywhere, the issue is to find how to remediate the visitor

experience. How to increase visitor engagement with the museum and its exhibits? Experimentations and research emerged in the last forty years to start understanding what kind of interactive apparatuses could have positive effects on museums offering them to their public.

We have seen many experimentations or implementation of technology in the museum since the early days of computing systems. Interactive technology is penetrating museums as mediation tools but also interactive technology-based artwork. While the former type is proposing remediation of the existing space and exhibits of a museum, the later is offering a new type of exhibit that integrates the interactivity as part of the exhibit itself.

Obviously, technology has evolved a lot in the last forty years, and it allows new apparatuses behaviour that was not possible before. Results of experiments have shown a high interest for all stakeholders, as we will show later. It is becoming a clear trend in museums to investigate the integration of technological apparatuses. However, even after several decades of experiments, research and analysis, there is no accepted classification for interactive apparatuses, and the definition of interactivity itself is still very debatable, and no proposal has emerged.

Regarding research on the museum with interactive apparatuses, all have been about the audience engagement towards an interactive apparatus. The topic is vital - particularly for a museum - and more investigation is needed in this area; however, understanding interactivity and classify it outside the perspective of the engagement is still a field that is overlooked.

Finally, we are now seeing a new type of experimentations to place the visitor at the centre of the museum. Whether it is an invitation for visitors to participate in collaborative exhibits or events that invite participants to re-imagine some aspect of the museum, the technology is the toolbox to enable new experiences through some non-conventional creative methodology.

The focus of this research is on the cross-section of the three phenomena discussed above:

- Museum - the public space that gives the context of this work.
- Interactive apparatus - the remediation tools created for the museum.
- Hacking methodology - the creative process and methodology promoted to create an interactive apparatus and experiment it.

The purpose of this research is to propose a holistic approach to the interactive apparatus. We will focus our study within the context of museums, and in particular through the study of apparatus developed with a hacking methodology.

Not only this research will look at technology integration and apparatus, but as importantly, it will also investigate the creative process behind our study case and how it could be valuable for museums.

The personal interest to start this research came after discussions with Professor Álvaro Barbosa and in parallel, with a friend, Yves-Armel Martin, one of the founders of Museomix. He invites us to participate to Museomix in 2013 in *Musée Dauphinois* -Grenoble, France - to experience by ourselves and understand the new type of approach within the context of the museum.

Moreover, as a professor at the University of Saint Joseph, Macau, in the Department of Design and teaching interactive design, we were interested in both the technical aspect and the creative methodology.

1.2 Research Questions

Current academic publications are focusing on analysing a specific interactive apparatus or interactive artwork with their criteria, but there is no holistic methodology that could help us analyse and compare interactive apparatuses based on a scientific approach.

The present research main goal can be described as: to define a classification for interactive apparatuses in a museum as a catalyst to understand their interactive properties.

After a systematic analysis of the problem, several sub-questions have arisen and are listed below, according to the scientific areas of our theoretical framework.

On interactivity,

1. Can we characterise interactivity based solely on its inherent properties?
 - a. What is interactivity in the context of this research?
 - b. Can we study interactivity without the audience engagement context?
 - c. Can we identify the critical attributes of interactivity?

On a Framework,

1. Can we propose a framework to assess an interactive apparatus?
 - a. How to measure, analyse, compare, share interactive apparatuses?
 - b. Can such a framework be relevant outside the context of this work?

On a Methodology,

1. Is a hacking methodology a possible approach to innovate in museums?
 - a. Can we identify the strengths and limitations of such a methodology?

- b. Can a hacking methodology propose new ways for museums to approach their work and expertise?

1.3 Methodology

In this section, we present an overview of our research design and methodology, listing and describing the most important steps that led us to the conclusion of this project.

This research is proposing a two-fold approach:

1. An experimental study through a study case which generated the majority of our dataset for further analysis.
2. Practice-Based research - research generated by the live practice - based on two projects created by the author.

1.3.1 Literature review

The first two years were partially dedicated to the literature review and state-of-the-art research. We first investigated the concept of interactivity as well as Interactive Apparatuses in Museums. We then turned to the hacking concept.

1.3.2 Preliminary Research Experiments

The first three years were also used to experience with the hacking approach by joining several international creative marathons, mainly in museums but also in diverse contexts such as church and university.

1.3.3 Framework Formulation

After a good understanding of the theoretical background and the preliminary experiences, we designed the conceptual framework as well as we defined the research methodology for the data collection.

1.3.4 Experimental Study and Data Analysis

Based on empirical research, we analysed a set of interactive apparatuses through the proposed framework. The research data was collected from prototypes created over four years of Museomix events. The dataset collected by the methods described above was statistically analysed - descriptive statistics.

1.3.5 Discussions

The final step engaged in a discussion based on the whole research as well as the data analytics generated through the proposed framework. We finally included a critical analysis of our findings and framework, and possible future work is suggested.

1.4 Thesis structure

In this section, we present the structure of the thesis, along with a brief description of each chapter. This thesis is divided into two conceptual sections:

- The contextualization and theoretical framework,
- The experimental process and analysis.

1.4.1 Contextualization and Theoretical Framework

In this section, we present the results of a systematic literature review on the thesis topics, divided into four chapters, namely:

- Chapter 2 - Interactivity. We cover the literature review and contextualization of interactivity as a complex phenomenon with many definitions.
- Chapter 3 - Hacking. We define the term hacking from its origins to the methodology used in this research and based on the hacking concept.
- Chapter 4 - Museum. We revisit the definition of a museum, its challenges and existing solutions to stay relevant in a digital world.
- Chapter 5 - The Spectrum of Interactivity. In section 5.2, we propose the Multivariate Analysis Framework for Interactive Apparatus as a base for our experimental study.

1.4.2 Experimental Process

In this section, we present a detailed description of the experimental process and development of the research tool, along with an analysis and discussion on the collected data and further findings.

- Chapter 5 - The Spectrum of Interactivity. In section 5.3, we present the first implementation of a web application to create a dataset for our proposed framework.

- Chapter 6 - Experimental Study. We introduce the experimental study and its context, as well as two personal exhibitions as a possibility to extend our framework.
- Chapter 7 - Data Analysis. We analyse the data collected through the experimental study and present some initial conclusion.
- Chapter 8 - Conclusions. A chapter dedicated to present the main contributions of this research project and future work to investigate in this field.

Chapter 8 is followed by the bibliography and three appendices containing technical work related to our work.

We invite the reader to continue on the journey with us on the following chapters.

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CHAPTER II

Interactivity

“Interactivity: a cyclic process in which two actors alternately listen, think, and speak.”
(Crawford, 2000).

“We didn’t need a special word for interactivity in the same way that we don’t - yet - need a special word for people with only one head.” (Adams, 1999)

2.1 Introduction

This chapter proposes a definition of the concept of interactivity through a literature review by presenting several publications which are setting the fundamentals for our research. These studies have all been developed in the context of the interactive art field; they also have developed taxonomies to identify typologies of interactivity. However, most research and experimentation focusing on interactivity are always analysing the audience engagement toward the interactive apparatus (Edmonds, 2010).

Interactive apparatuses, particularly in museums, have stimulated a great deal of theoretical and philosophical debates as well as analysis frameworks to classify them with some taxonomies. However, as shown later in our research, the majority of those publications are studying interactive apparatuses through the angle of audience engagement. By trying to understand and evaluate the engagement of the interactor, meaning the indirect consequences of the apparatus - or installation - outcome, we are trying to appraise the consequences of a specific apparatus before assessing the installation itself which has specific attributes. They are therefore classified through an indirect prism, but rarely they are analysed through a direct approach that would describe its properties and its potential interactive behaviour.

The purpose of our research is not to define what is a “good” interactive apparatus -opposite to a “bad” system - in the sense that we are not defining the interactivity based on the audience engagement. We understand the ultimate value of the engagement evaluation and measurement, particularly for the artist perspective or even the museum perspective. However, we believe the engagement of an audience can have some particular characteristics such as local culture, social background and much more. These aspects are complex and multi-disciplinary per nature, and we will not consider them in our research. This is the reason we are proposing in this chapter, and particularly in chapter 5, a set of tools to intrinsically understand interactive apparatuses as well as a standardised process to analyse and compare their attributes and functions - as defined by their authors.

In this chapter, we will define the two key terms for our research: interactivity and apparatus by giving a background review. We will then, in the second part of this chapter, propose how we are embodying these terms in our research by extending their definition to our research field.

2.2 Definition

Before we start, it is essential to understand that both terms “interactivity” and “apparatus” still have various definitions, sometimes opposite and controversial. This is why, in the context of this research, it is vital to understand which definition we are following along and what is not in the scope of this research.

2.1.1 Interactivity

The word “interactivity” has been defined in the last sixty years within various research and experimental fields and with different perspectives. It has been defined with very vague terms,

reflecting a continuous transformation of the fields of technology and new media but also various methodologies and researchers approaches. Confusion is also made in the universal language and mass media between interaction and interactivity where they are most of the time interchangeable terms loosely covering apparatus linked with technologies or even simple human interactions.

Not only the definition is often broad in scope or narrow down to a specific study case, but we also must recognise that we could list many definitions that are opposite or to the least rejecting other definition options.

Although the second citation at the beginning of this chapter from Douglas Adams seems to indicate that interactivity is a useless concept, we will show that the majority of researchers consider it as a fundamental concept in the evolution of relations between technology and humans.

We can refer to the first citation at the beginning of this chapter from Chris Crawford, where the author defines interactivity as a dialogue between two actors and in (Crawford, 2000) specify that one actor is a computer-based system and the other a human. We could represent this concept with Figure 1. He emphasises on the cyclic process between listening, thinking and speaking.

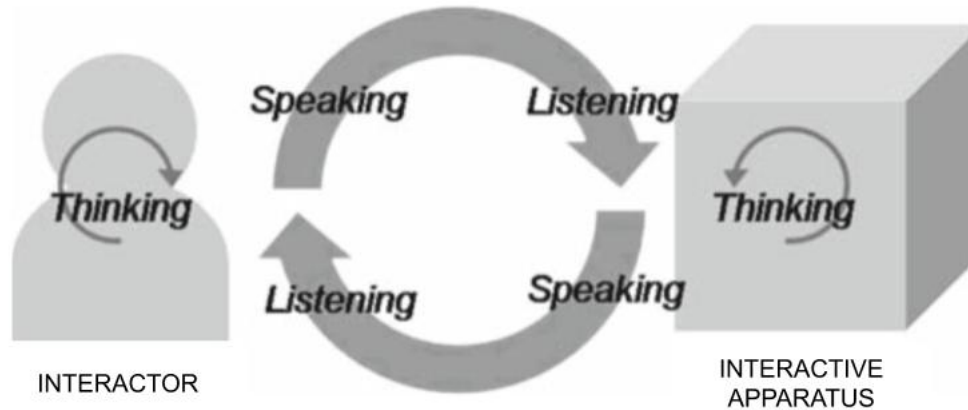


Figure 1- Interactivity Cyclic Process based on (Crawford, 2000)

Following this idea of a cycling process and the capability of the interactive apparatus to “think” or as (Weissberg, 1999) called it, the reflexivity property, he stated that the interactivity is specifically a property of the software. Weissberg concluded that interactivity is a specificity of software - and therefore a computer-based system, opposing it to the human physical environment that is reactive only.

2.1.1.1 Interaction versus Interactivity

Interaction can be described as a behaviour one engages in. The Cambridge Dictionary defines interaction as “an occasion when two or more people or things communicate with or react to each other”.

Following the Communication Theory, the Interactional Model, as discussed by (Cobley & Schulz, 2013) suggests that communication - verbally or not - works bi-directionally in a cooperative fashion. We can, therefore, identify the most common form of interaction as a conversation where a person will say something (the sender), and then another person (the receiver) will respond with a level of relevance in the response such as a comment, an elaboration or even another question. There is a need for a degree of relationality in the conversation and relevance between the different exchanges over time. A random conversation

without any causality between each exchange cannot be considered as an interaction. At the opposite side of the spectrum, a conversation where one person would only repeat the words of the other person cannot be considered either as an interaction.

Interaction is therefore considered in our research as a person(s) to person(s) communication whereas interactivity will be specific to a property of an apparatus that can enter in communication or exchange with one or several people.

To characterise a person interacting with an interactive apparatus, (Baboni-Schilingi, 2003) as well as (Laurel, 2013) have suggested using the term “interactor” in order to differentiate it from the visitor. It also has been used by (Sena Caires, 2004), and we choose to use it in our research as well.

However, we must highlight that interaction is a term also used in some research fields linked to Human-Computer Interaction (HCI). Researchers in HCI such as (Svanæs, 2000) consider the term interaction as the act of interacting, particularly considering computer displays and new media.

In the context of our research, we will take the position of the majority of artists and technologists: interaction is related to human-to-human communication only. In the next sub-chapter, we will define what the interactivity is and what are the conditions for the interactivity.

2.1.1.2 About Interactivity

In “Narrative as Virtual Reality”, the author, Marie-Laure Ryan, study the interactivity through interactive art - like most authors - and present the interactivity as a continuum with possibly multiple and different manifestations, ranging from reactive to random. She mentioned that to be interactive is to “make use of user input” (Ryan, 2001). Following more technological approaches and taxonomy by Edmonds and others - discussed later in this chapter -, she

describes interactive art as a spectrum through a taxonomy rather than a unique type of human-computer interaction.

David Saltz is, for his part, proposing that interactivity is defined by three events that must happen in real-time:

1. A sensing or input device that translates certain aspects of a person's behaviour into a digital form that a computer can understand.
2. The computer outputs data that are systematically related to the input - i.e., the input affects the output.
3. The output data are translated back into real-world phenomena that people can perceive (Saltz, 1997).

He also proposes a taxonomy but what seems very relevant from his point of view is the notion of input and output of and from the computer-based system. We will see in Chapter 5 how can we integrate the input and output of an interactive apparatus within our multivariate framework.

However, the philosopher Aaron Smuts argues in his article titled "What Is Interactivity?" in the *Journal of Aesthetic Education*, that interactivity can only have one definition for interactive art: an interactive apparatus "must be responsive in a way that is neither completely controllable nor completely random". His final definition, based on the comparison of the human conversation, is stating:

"Something is interactive if and only if it (1) is responsive, (2) does not completely control, (3) is not completely controlled, and (4) does not respond in a completely random fashion."
(Smuts, 2009)

Although his proposal seems to us very interesting, it is limiting interactivity to a very small list of computer-based apparatus where the system to be considered must have some artificial intelligence to create an interaction similar to a human conversation.

He also introduces two important concepts in his article: 1) the notion of the interactor control and 2) the notion of the temporality of the interactivity. As humans, we are naturally trying to get control over things that we are discovering for the first time. As long as we are in the discovery phase, then the apparatus is interactive, however, once we understand how to control it, then it merely becomes responsive, and the interactivity disappears for this person. Therefore, interactivity can be a property of an apparatus that is time-sensitive based on the interactor interacting with it. Not only it could be limited in time, but it is also a factor of the interactor, and therefore, interactivity can be perceived differently by different interactors. A typical example of such temporality is the video game, where the gamer needs a period to understand the game - interactivity - and then once mastered - by means of repetition and training -, he should be able to finish the game with full control theoretically.

This definition of interactivity is based on the observation of human conversation and translating these principles to the interactions between computer-based systems and humans. Even if this is an extremely specific and interesting definition of interactivity, it does not fit the purpose of our research, and we will show in Chapter 5, how we integrate important elements of his definition in our analysis framework for interactive apparatus.

On the other extreme of the scale, we can discuss as well the French philosopher Merleau-Ponty. Although he did not study the term interactivity, he talked about perception and how nothing is passive, even when someone watch a painting in a museum: “When we perceive objects with our eyes this is not a passive process of stimuli reception, but an active movement of the eyeballs in search of familiar patterns” (Merleau-Ponty, 1945). Although we agree with

his analysis, we must state that we are considering in our research - as many authors as well - that interactivity is an attribute of a computer-based apparatus to enter in relation with an interactor. Therefore, the interactivity is a property of an apparatus as a potentiality; it is built-in but only active if an interactor (voluntarily or not) trigger it through its input system.

2.1.1.3 Conditions of Interactivity

The conditions for interactivity can be defined as follows:

1. The interactive apparatus is composed of physical and digital interfaces, allowing input and output as a means of relation with an interactor.
2. The physical interface of the apparatus is controlled by the digital interface, which can be considered as a computer system, whether it is a simple microcontroller or a powerful full-fledged artificial intelligence computer.
3. The interactivity is only an attribute of a static apparatus, and it is, therefore, becoming interactive only when a communication is initiated with an interactor. If the person decides to remain an observer, then the interactivity cannot happen either.

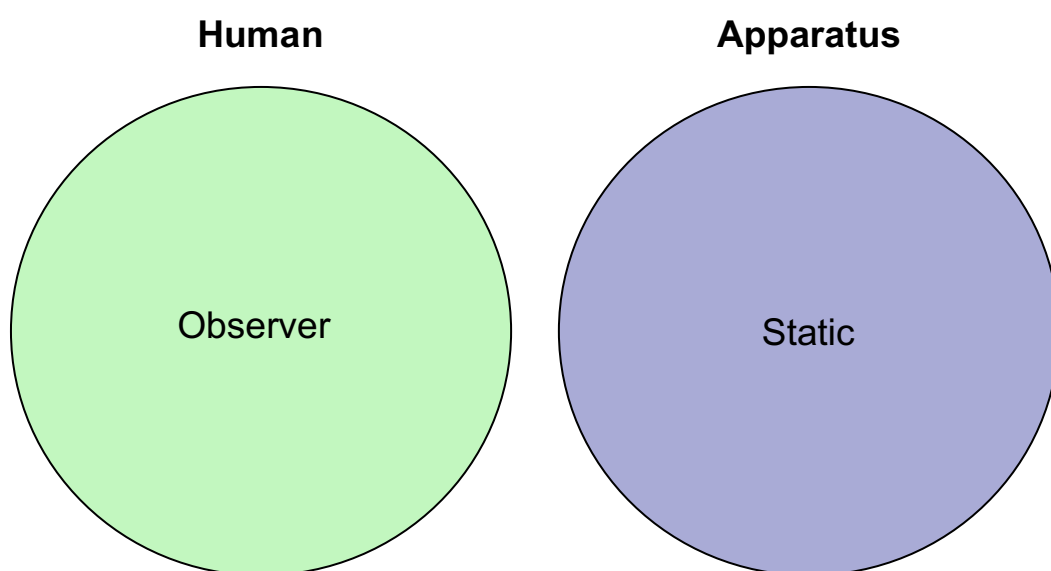


Figure 2 - Euler diagram - non-interactivity between an observer and a static apparatus

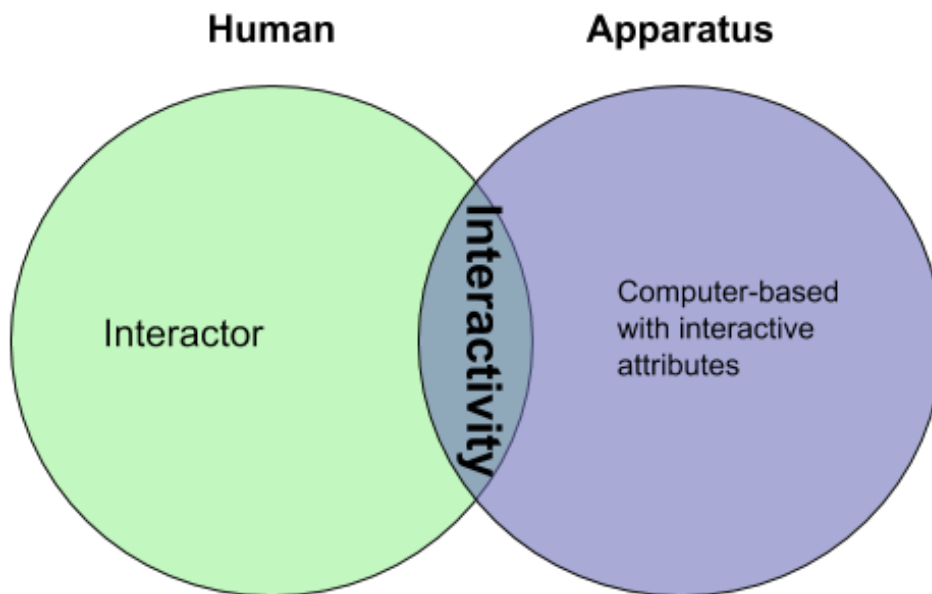


Figure 3 - Venn diagram - Conditions of interactivity

Based on this definition and the conditions of interactivity we can conclude with (Smuts, 2009) that the notion of temporality in interactivity is essential: an apparatus can be interactive for a certain time. Firstly, the interactivity attribute of the apparatus must be activated and therefore can as well be deactivated and secondly, the person must also be willing to enter the communication by becoming an interactor and not remains only an observer.

An essential feature of interactivity is that it is mutual: interactor and apparatus each take an active role. In this sense, we can discard the words of Adam Douglas cited earlier as well as disagree with Manovich when he said ““In relation to computer-based media, the concept of interactivity is a tautology. Therefore, to call computer media “interactive” is meaningless – it simply means stating the most basic fact about computers.” (Manovich, 2001).

2.1.1.3 Taxonomy

Researchers in interactive arts have proposed a taxonomy to classify art exhibits (Graham, 1997) (Bell, 1991) (Edmonds, 1977) and our research will be based on their work. However, they are proposing taxonomy very specific to computer-based interactive arts, where we are trying to extend their approach to a more generic term of interactive apparatus that can be applied to any relationship between human and apparatus in a museum context.

A taxonomy proposed by Cornock and Edmonds in 1977 and cited by (Bell, 1991) is proposing a classification of art exhibits as such:

- (a) The static system: the artwork does not change; the familiar class of traditional art objects.
- (b) The dynamic-passive system: an art object is caused to change with time by the artist's program (e.g. kinetic art) or is changed by factors in the environment (e.g. Calder's mobiles). The participant within such a system has no control and cannot alter anything.
- (c) The dynamic-interactive system extends the dynamic-passive system to include output from a participant to an artwork, leading to a feedback loop. The system can be very rich, though the speed with which the participant may exhaust the set of possibilities means that the result could lack substantial interest or value.
- (d) Dynamic-interactive system (varying): A special case where an artist modifies the system or process in a way not allowed for in its original definition.
- (e) The matrix: the total system within which the art system and the participants perform. A varying system leads to a varying matrix. Within the matrix, the participant plays an integral and interactive part. The artwork is the designed subsystem with which he interacts. A participant must be seen simply in terms of the inputs to that subsystem

(as an exogenous variable); to try to design a system that takes a total account of a participant would present an incommensurable problem.

Cornock (Cornock, 1977) outlined the four variables of interaction: Artwork, audience, time and environment. The artwork-audience relationships are the primary areas of interest for this research.

We are founding our concept of interactivity based on a lot of research within the interactive art field; however, we will show in Chapter 5 and 6, that we can extend these types of taxonomy outside the art field.

2.1.2 Apparatus

“the tools or other pieces of equipment that are needed for a particular activity or task”
(Oxford English Dictionary, 2010)

“the structure of a system or an organisation, particularly that of a political party or a government” (Oxford English Dictionary, 2010)

The second definition cited above is a possible translation - although contested - from the French term “dispositif” coined and defined by philosopher Michel Foucault (Foucault & others, 1972) and theorised by (Agamben & Rueff, 2014).

However, as we are focusing our research on interactive systems within the context of museums, we will concentrate our work on the first definition: an assembly of technologies targeting a specific goal defined by its creator.

Contrary to research cited earlier, we are not focusing our research only on interactive art, but we are extending it as well to any computer-based systems added to existing artwork, physical structure or place and supporting some possible interactivity with an interactor.

2.1.2.1 Input and Output as Interfaces of a Relation

As we described earlier that interactivity would need actions from both sides: the interactor and the apparatus, it seems logical to identify input and output for both of them as well. These interfaces are our natural way of communication with the external world, whereas, for an apparatus, it is a technology-based interface - at least as of today technology advancement.

The interfaces - input and output - of a person are evidently his/her senses: vision, audition, touch, smell, taste, balance and movement are the most important - knowing that the number of human senses is still a debate in the scientific community.

An apparatus must integrate some interfaces to understand at some level the interactor as well as some interfaces to react in a comprehensible way to the interactor. An apparatus, using sensors and actuators, should facilitate a certain communication with the interactor. Obviously, technology will play an essential role in this communication, and those interfaces have evolved and will continuously evolve to allow more possibility of interactivity.

Technology provides us with more and more technical solutions to interface with the human senses; it is, however, worth to note that some of our senses are still not well integrated, an obvious example would be the nose. It is incredibly complex with the current technology to generate smell or to be able to detect odours; therefore, it is seldom used in interactive apparatuses.

2.3 Conclusion

In this chapter, we have described what is interactivity according to (Smuts, 2009; Svanæs, 2000; Kwastek, 2008; Crawford, 2000; Weissberg, 1999), and we have proposed to consider

interactivity as a property of an apparatus. The interactivity is triggered only when a person actively becomes an interactor (Laurel, 2013) (Baboni-Schilingi, 2003). We also have shown some possible taxonomies to classify and understand interactive apparatus (Bell, 1991) (Edmonds, 1977). However, those taxonomies have all been defined in a one-dimension scale only - and all toward the engagement of the interactor, whereas we would like to propose through this research a multivariate taxonomy to try to capture the inherent properties of these complex systems.

CHAPTER III

Hacking

Understand and Subvert

“Sometimes you have to demonstrate a thread to spark a solution”

- Barnaby Jack, Security Expert/Hacker

3.1 Introduction

The word hack has taken on multiple meanings, but in the last century, it has been commonly associated with an individual or a collective, technological skill, to access a remote computer system illegally. However, over the last fifty years, the terminology of hacking has changed, offering new definitions. This chapter proposes to review and define what hacking means outside its illegal meaning as well as describe a creative methodology approach based on it. Events such as hackathon or places such as hackerspaces have started transforming the meaning of the word toward a positive experience and possibly a creative tool. However, little literature has yet studied these recent phenomena and what could be their impact on cultural institutions. Our study proposes, based on events organised in the last decade, a possible new creative methodology in the arsenal of creative tools for cultural institutions and particularly museums.

The very first impression when we pronounce the word “hacking” is, in the vast majority of the time, a rather unpleasant and harmful feeling toward this dark and misunderstood term. Our first objective here is to identify what are the different meanings of this word over time; and present which is our definition for the research presented in this thesis. We do not pretend to work as linguists but rather understand the hacker community, how they are defining themselves and what creative process are they using behind their skills and technologies in order to accomplish a form of creativity.

3.1.1 Origins of the word

The word “hack” seems to appear in English in the XII century from German and Dutch languages. As defined by the Oxford English Dictionary, the first meaning is to “cut with heavy blows in an irregular or random fashion”. Since then, the word has been used in different contexts, for example, as a noun in falconry or horse riding. Another unusual usage of the verb hack is to signify, usually in a negative way, the capacity to manage or cope with a situation.

3.1.2 Pre-Computer Era

While discussing the very early origin of the word hack and before moving on to the modern definitions of the same word, we should mention some early “hack” before the computerised age post World War II and before the term “hack” was referring to digital activities.

In the late nineteenth century, when the Bell corporation was deploying telephone lines, according to (Sterling, 1993), we can situate the very early telephone phreaking activities by teenagers. Telephone technology was not yet digital, but some passionate engineers tried to understand how the technology was working and hacked the telephone system to use it to play tricks to other users - although annoying, not directly illegal - or, less playful, used the phone without paying any fee and even more illegal activities.

Later, early twentieth century, we can also trace a well-known story related to the wireless telegraph technology that Guglielmo Marconi was trying to promote as related by (Hong, 1996). In 1903, a conference was organised in London to demonstrate the technology and ensured it was secure enough to be deployed at large scale. However, Nevil Maskelyne, a magician and inventor, proved that the technology was not yet safe since he was able to insert insults in Morse code during the live demonstration of the wireless transmission! This event is very often referred to as the first hack in the history of modern technology.

3.1.3 Computer Hacking

Needless to say, that the mainstream usage or at least one interpretation of the word hack is nowadays far from its original meaning from the thirteenth century; With digital technologies invading all sides of our modern societies, “hack” turned into a verb related to a particular type of computerised activities. Most of the time, in the understanding of general public and mass media, these activities are perceived, discussed and understood as illegal activities and therefore legally punishable. To hack, and the derived noun “hacker”, are clearly understood as computerised attacks against a digital computer system (Parker, 1976), view as unauthorised access to data in order to gain some profit. The noun “hacker” is nowadays defined as a synonym of terms such as cybercriminal, pirate or computer criminal.

3.1.4 Of Pirates

Pirate is indeed an interesting synonym with a long history of sometimes heroic stories and legends but most of the time greed, personal interest and violence. The vast majority of these stories are related to sea criminals, but we will consider the term in a broader sense.

What is more interesting in the piracy, it is that it is always in the perspective of individuals or small groups fighting against a specific establishment. The establishment is here defined as a broad concept of a major organisation such as a government, a financial institution, a large corporation or celebrities and wealthy individuals. Pirates are, therefore, by definition, anti-establishment, precisely like hackers are defined. It is not surprising to read in media the term pirate to describe hackers.

However, the term pirate is not only referring to the dangerous criminal but as well nowadays to copyright infringement organisation such as the well-known “The Pirate Bay” which had a significant influence on international copyright relations as mentioned by (Li, 2009). It was

covering at the same time criminal activities as well as provoking an establishment of digital industries to adapt and rethink the coherence and benefits of the copyright in the digital environment. An example such as Napster with the music industry, has shown as well how an illegal system, according to international copyright laws, contribute to new, innovative and viable business models (Choi, 2006).

An establishment is by its nature not open to any change in a system that it controls and benefits from. Pirates, by their definition, are provoking, most of the time illegally, but can sometimes be a source for improving an existing situation and find a creative solution - provided that a dialogue is possible between the two entities. Barnaby Jack, a well-known hacker and cybersecurity specialist, said in a conference: “Sometimes you have to demonstrate a threat to spark a solution”.

3.1.5 The Hacker Perspective: hacker vs cracker

To better describe hacking, one needs first to understand hackers. Besides the definition of “hack” from media and establishment, it is interesting to understand what hackers have to say about themselves and how they would define their intentions and activities. This section will try to give a different perspective, obviously not to justify illegal activities but to understand the origin, roots and deep motivation of hackers.

The modern usage of hacking started in the late 1960s at the Massachusetts Institute of Technology - MIT - in a computing subculture where students were curious to learn how mainframes were working and started to play with them as a way to better understand the systems and their fundamental structures. Since those very same systems were mainly closed systems and inaccessible, it was a matter of time before students started to access them illegally.

In the Jargon File (Raymond, 1975), the author proposed a glossary for computer programmers, and he listed eight definitions for “hacker”, here is the list:

1. A person who enjoys exploring the details of programmable systems and how to stretch their capabilities, as opposed to most users, who prefer to learn only the minimum necessary. RFC1392¹, the Internet Users’ Glossary, usefully amplifies this as: A person who delights in having an intimate understanding of the internal workings of a system, computers and computer networks in particular.
2. One who programs enthusiastically - even obsessively - or who enjoys programming rather than just theorising about programming.
3. A person capable of appreciating hack value.
4. A person who is good at programming quickly.
5. An expert at a particular program, or one who frequently does work using it or on it; as in ‘a Unix hacker’.
6. An expert or enthusiast of any kind. One might be an astronomy hacker, for example.
7. One who enjoys the intellectual challenge of creatively overcoming or circumventing limitations.
8. [deprecated] A malicious meddler who tries to discover sensitive information by poking around. Hence password hacker, network hacker. The correct term for this sense is cracker.

While definitions 1 to 5 are correlated and mainly related to computer enthusiasts, definitions 6 to 8 are much more interesting: 6 and 7 enlarge the application of the term hack to other fields of application outside computing; while definition eight is marked as deprecated and clarifying the difference between a hacker and a cracker.

¹ <https://tools.ietf.org/html/rfc1392>

It is interesting to note how, since the very early modern hacking days, the distinction was proposed between a hacker, as an enthusiast about computer systems, and a cracker, as a perpetrator of illegal activity to steal information or data.

Secondly, we can clearly understand how a hacker is defined by enthusiasm or expertise in a specific field. We identified mostly hacker as computer enthusiasts, but it is not strictly the only application, as shown in definition 6 and 7.

Finally, and more importantly, a hacker is also presented as a person who strives at finding creative solutions to specific problems or limitations in its field of expertise. A hacker could, therefore, be defined with the following three criteria:

1. A person who strives at exploring yet undiscovered solution to a problem within an area of expertise.
2. A person who enjoys and looks at the problem as a challenge. A challenge for himself or herself but as importantly, a way to challenge the surrounding system itself.
3. The notion of enjoyment or playfulness is an integral part of the process itself to the solution.

Recently, the President of Russia, Vladimir Putin, declared: “hackers are free people just like artists who wake up in the morning in a good mood and start painting.” Although his declaration was related to illegal activities, we believe this over-simplification carry the fundamental definition we proposed earlier. We can also understand that most hackers are often political, social or artistic activists. A good example is (Dorne, 2016) a book proposing hacks to remain anonymous and take control of our privacy - nothing illegal though.

3.1.6 Internet Philosophy

Another aspect of hacking must be understood as well: its root in the original Internet culture. This culture, one could say utopia, could be resumed as sharing information for the benefit of all. We can find the same philosophy nowadays in the free and open-source movement, either for software or hardware which are sharing similar DNA roots as hackers. As described by (Levy, 2010), Richard Stallman, from the MIT, founder of the Free Software Foundation and promoter of the copyleft, was, like many others, in the early age of the hacking phenomenon. Even nowadays, the majority of the Internet infrastructure is working with software developed by well-known hackers such as Linus Torvald and others.

This philosophy is promoting freedom, the right to privacy, not so much the free of charge. In the book titled “The Hacker Ethic” Pekka Himanen traces the root of this philosophy in a rejection of the protestant ethic. The protestant ethic, basis for modern capitalism, is defining the work as a means to money. The hacker ethic is fundamentally in opposition as proposing to work out of passion and to generate socially valuable outcomes.

3.1.7 From Pirates to Robin-Hood

In light of this new definition, which could be seen as the other side of the same coin, hacking is also identified as a positive force to stimulate change and sometimes protest against wrongdoing that some would consider as revolutionary or at least provocation. As it is essential to understand how hackers can be considered as pirates, it is also essential to recognise that some hackers can be as well viewed as some new version of Robin-Hood: they often see themselves as one of the ultimate protections of the less fortunate in the society. This is also a topic which has been fantasised by the movie industry from Hollywood with movies like “V for Vendetta” (McTeigue, 2006), “Hacker” (Softley, 1995) or the recent “Anon” (Niccol, 2018).

3.2 Creative Hacking

As discussed earlier, we understand that hacking is not restricted to cybersecurity and computer systems, but rather it is more a way of challenging an existing status quo and therefore can be applied to a much larger audience. This chapter will introduce some of the major types of organisations that have their inspiration rooted in the hacking approach.

3.2.1 Introduction

We consider the term creative - or creativity - as described in (E De Bono, 1995): creativity is not about brainstorming, nor setting ourselves in a childlike innocence mindset or using our ignorance to get a fresh look at a problem. The mindset mentioned above can obviously generate creativity, but unfortunately, this “natural creativity” is not reliable and not always possible. The normal behaviour of the human brain is to create routines and patterns and to follow these patterns (Edward De Bono, 1970). On the contrary, creativity is an unnatural process, a transversal action that needs to separate our approach from routines.

Creativity has to be grounded; the novelty as such is not an objective but rather the practicality of a solution, an applicable result. It is also not necessarily only a “fun, lively and crazy” process; it can be organised and rationalised - serious creativity - as (Edward De Bono, 1970) shown with his “six hat thinking system” and “lateral thinking”. It is now well accepted that creativity has attributes such as divergent thinking, problem finding and incubation (Candy & Bilda, 2009) that make it a very specific human process compare to our standard patterns such as “routine structuring, planning and problem solving”.

The “Creative Engagement Model” (Bilda, Edmonds, & Candy, 2008) was developed within the context of interactive art in Beta_space, Australia. However, we found that a lot of these defined principles apply to any interactive systems in museums and even to a certain extent to

the creative process, this is why we decided to use the relevant principles to present our approach as well.

3.2.2 Hackathon

In 1999, the first hackathon - the contraction of hack and marathon - based on the hacking approach described above, was organised in Calgary, Canada. It is nowadays a widespread type of events organised around the world.

Hackathons are events from one day to a maximum of three days, where software developers - from less than ten to hundreds - gather in teams to work on finding a unique solution to a specific problem. Often, hackathons will finish with each team presenting their work, and ultimately a team could be selected as the winner - although this part is optional and up to the organisers.

Most hackathons tend to promote the idea that it can have a social impact of sort by creating innovative solutions; some are criticising this mantra (Porway, 2013). It is necessary to highlight that in an average period of two days, the majority of the proposed solutions are only at an early prototype level, and a lot of them will never see any implementation. However, again, coming back to the root of hacking, we must understand that prototypes are as important as the creative process that the team went through and the social network that those events are creating. A recent example has been the VHacks, the first Vatican Hackathon, whose was inviting students from around the world to find a technological solution to social problems such as social inclusion, migrants and refugees or interfaith dialogue. It seems evident that a three days events, will not solve those universal questions but the intent was to emerge with possible

innovative ideas as well as encourage participants to understand, think and even empathise with those topics.

3.2.3 Hacking Public and Cultural Spaces

Hackathons are nowadays very popular all over the world and have been adapted to all sorts of environments such as makeathon - targeting makers -, health hackathon or Museomix.

Museomix is a new type of events, created in 2011 in Lyon, France. It is now an annual three-day event in museums around the world. The objective is through an open innovation and creative process - based on the fundamentals of hacking - to propose innovative perspectives on the museum, its collections, its stakeholders or its environment.

This event is relevant for this research for several reasons:

1. It is a hackathon on the format - or how it is called a creative marathon - but it is not specific to software or hardware development only. It is encouraging a mix of expertise to offer different perspectives and open ways to create prototypes.
2. Museomix is focusing on cultural and museum hacking where participants are encouraged to propose innovative or provocative prototypes under a copyleft license. The museum experiments in-situ these prototypes and decides of their relevance for the long-term.

These principles have since been adapted to other public and cultural environments. We will discuss Museomix in detail in chapter 6.

3.2.4 Hacking and Arts

Arts and hacking have a lot in common as we are going to see in this section.

Art is usually considered in its comprehensive spectrum as an expression of creativity. Artists are showing us their perception of the world and by their perspectives, techniques or symbologies they are questioning us or at the very least questioning the position of the arts and artists in the society (Kozsilovics, 2016). Some artists define themselves as challenger or activist: by diverting the normality of space or object, they are indeed disturbing their perception but also disturbing our routine. Modern artists such as Banksy or Mark Jenkins, to cite a few - but we could include most taggers as well - are continually creating artwork or installation art to highlight some paradox in our society or denounce some human activities. They are indeed very much in line with the hacking approach. It is not something new to these artists, the XX century alone is full of artists questioning our beliefs or hacking the reality, Picasso to cite only one.

Art Hack Day (Chevrier, 2014) are events where artists will hack their environment, most of the time in the field of a city. In our postmodern societies build on non-stop flux of data and images, urban hacking transforms the public space into a canvas to create, to spark actions, reactions or discussions. This protest approach can also be seen as an echo to art movements from the early twenty century, such as Dadaism². Facing a public space and some areas of the arts more and more invaded by corporations and market institutions, hacking art can be viewed as a somewhat natural subversive counterweight.

3.3 A Hacking Methodology

In this section, we will identify what are the key factors to the creative methodology discussed earlier. Before detailing the conditions of the hacking methodology, we can resume the

² Dada: movement consisting of artists who rejected the logic, reason, and aestheticism of modern capitalist society.

objectives of a hackathon - or similar event: 1) It is about experimenting first, the process itself is as important as the final result, 2) to transform the original purpose of an apparatus or space and to propose new interactions to the public. The transformation can be either transgressive or evolutive.

Based on this definition and on the experience of all events mentioned in the previous sections, we are proposing the following key conditions for a hacking methodology.

3.3.1 Time Constraint

As we have seen in hackathons - events with a duration of one to three days -, the time is always integrated as a positive constraint. It is a constraint that keeps pushing hackers to find the essential elements of their project and focusing on those elements only. Since hackathons are also about finding a quick and sometimes not dirty solution, the time limitation is an enabler to take shortcuts and keep a short cycle for prototyping and testing. It is always about experimenting, not how it is done technically.

3.3.2 A Mix of Talent

The experience of Museomix over the last few years shows us how important it is to have a controlled variety of expertise. This diversity allows us to create different perspectives and generate divergent discourse. Through the prism of the time constraint, these perspectives will eventually promote the best approach; it is indeed seldom to see a team blocking without being able to identify what is best for them. This approach encourages each participant to stay open-minded and understand different perspectives to find a solution finally.

3.3.3 Guidance and Support

In order to manage the time constraint and possible conflict in teams or simply human relations, it is important that the organising committee understand its role and do not ignore any issue identified. But the guidance and support are not only about human conflicts, but it is also by providing technical support with equipment and services such as access to a digital fabrication lab or a hardware bank.

3.3.4 Playful Environment

We have earlier discussed how a hacker works with and by enthusiasm, we could even say a passion. Creating such an environment is the role of the organising committee, and it is an important part of the creative process. It could be overlooked in the light of more traditional methodology, but in the hacking approach, it is always a key factor and a stimulus for the participants. Since all those types of events are not remunerated, participants will feel a certain natural need to be cherished and considered. The physical space for the team to work, the common areas to socialise and relax provided are all part of the welfare and mood of the event and participants.

3.3.5 Communication

Both internal communication for the participants as well as external communication are important elements for a successful event -whether it is about the hacking methodology or any other type of events, of course. However, a specific element within the proposed methodology is the live coverage of the event, mainly through social networks such as Twitter, Facebook, Instagram and Youtube. Some events, such as Museomix have a team dedicated to media coverage and even live coverage between all the museums around the world.

3.4 Conclusion

This chapter presents a methodology inspired by the hacking movement, and that has been already experimented in some cultural institutions around the world, for example:

- Museums: *Circuito Liberdade Belo Horizonte* in Brazil, *Philadelphia Museum of Art*, *Arts Decoratifs* in Paris.
- Libraries such as the Stanford Library or the New York Public Library,
- Churches such as Eglise Sainte Blandine in Lyon or the Vatican City more recently.

We can also identify a new type of corporate hacking: companies are using this philosophy to generate internal innovation - Google or Facebook are claiming to be companies of hackers -. Also, with an even more integration in the structure of the company the “Growth hacking” (“Growth hacking,” 2018) appeared as a transversal new type of job to experiment with data to grow one’s company sales.

In a broader consideration, the methodology we are describing and the type of events based on it are also suggesting some interesting research questions, such as: is hacking an artistic process? Is the fact of creating a methodology from hacking not a paradox or contradiction coming from a subversive movement - like taming a wild animal? Could it be risky or dangerous to be a creative hacker? We hope with these questions to open a discussion and possibly new research on the subject.

Chapter IV

Museum

Public Space and Technology

“Whether you're going to a museum or a flea market or flipping through a book, always be on the lookout for something special.”

Kelly Wearstler

4.1 Introduction

In this chapter, we will first define what is a museum according to international organisations and the evolution of its role and responsibilities. We will also propose to identify what is a museum in the context of this research since we are focusing only on a type of technological experiments within museums. Then we will review a brief history of museums around the world and their milestones regarding interactive apparatus. Following the historical timeline of technologies in museums as well as sociological behaviour, we will expressly look over the last hundred years where modern museology started to investigate new possibilities and impact of media and technologies.

Finally, we will propose a taxonomy for technology-based interactive apparatus within museums as a way to classify and better understand the use of technological systems to develop museums around the world.

4.2 A Definition

Museums have been in our civilisation for more than five hundred years, and they have become over time a cornerstone of our cultural, sociological and political institutions. Museums are part of our civilisations to teach, remember, advocate or to wonder the public.

Over the centuries the number and importance of museums have grown as an essential motor for our society to disseminate and popularise significant knowledge and all areas of human production: whether it is arts, science, architecture and much more.

According to (Saur, 2011), we are estimating that about fifty-five thousand museums in two hundred and two countries are currently operating around the world with more than forty thousand of them registered to the International Council of Museums (ICOM). Interestingly, more than half of the fifty-five thousand were created since 1975. Organisations, governments and the society at large, see them, the majority of the time, as a common platform to share and debate in a safe and open environment. They have in time, and some are still today, used as a tool for propaganda for political or sociological agenda.

The traditional definition of the term museum from The American Heritage Dictionary of the English Language, 5th Edition is:

“A building, place, or institution devoted to the acquisition, conservation, study, exhibition, and educational interpretation of objects having scientific, historical, or artistic value.”

(Dictionaries, 2016)

The International Council of Museums³, created in 1946, define a widely accepted and more detailed definition of what is a museum:

“A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates

³ <https://icom.museum/>

and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment.” (“Museum Definition according to ICOM,” 2007)

This more comprehensive definition, role and responsibility of a museum is highlighting the following:

1. A museum is a non-profit institution;
2. It is not anymore about a building or place, although most of the time a museum is attached to a place;
3. A museum is at the service of the society and for its development and therefore open to the public;
4. A museum is not only exhibiting artefacts but also intangible heritage;
5. Finally, the notion of enjoyment is also introduced besides education and research.

Museums are nowadays playing a leading role in bolstering the creative economy locally and regionally. Museums are also increasingly present in the social sphere, acting as platforms for debate and discussion, tackling complex societal issues and encouraging public participation. However, it is interesting to note that over recent decades, museums have transformed, and re-invented their purpose, policies and practices, to the point where the International Council of Museums is considering to propose a new definition in the coming year to better represent museums diversities, challenges and responsibilities.

4.3 Museums across time

Human beings have always tried to express their feelings and convey their messages throughout history and with their technology of the time. One of the most known examples is probably the

Lascaux Cave paintings in France (Aujoulat, 2005). Humans are creating and expressing not only for themselves but also as a need to be recognised and to leave a mark in history. Over the centuries, humans have started to realise the historical value of some of those creations and the importance of saving them for future generations as a testimony of the past but also some time as a way of conveying a message or impose a power (Watson, 2007). The relation between art expression and our societies over the centuries have always been linked to power and communication.

4.3.1 Cabinets of Curiosities

Historically, the precursors of modern museums are considered to be the “cabinets of curiosities” - Cabinets of Wonder - in the sixteen century mostly owned by a royal title, nobles or wealthy merchants collecting arts and also exotic artefacts from around the world after explorers brought them back to Europe (Mauriès, 2011). Those cabinets could cover artefacts from arts to natural history, ethnography, archaeology and antiquities or religious and even superstitious objects. Some of the most famous examples of such cabinets are the Medici family or the Pope personal cabinet in the Vatican. Some of them were indeed the origin of some of the most prestigious museums known today, such as the collection of Sir Hans Sloane that became later the British Museum.

4.3.2 Modern Museums

The transformation to modern museums started to open to the public in the late seventeenth century and accelerated in the eighteenth century during the Age of Enlightenment across Europe. Most of them shared a similar objective to democratise the knowledge, to educate and to entertain the mass population.

Starting in the late nineteenth century, museums in Europe and North America have begun to question their strategic positioning in the modern society era continuously. Whether it comes from academic or curators themselves, we can read literature over and over very similar criticisms and questions about museums strategies related to media and technologies (Griffiths, 2003).

The very first experimentations of media and technologies by museums appeared at that time, starting the profound transformation of the museology world as we know it today. The two major factors that triggered these transformations in museums are:

- 1) the new modern society with large cities, higher education level and active and busy workers - creating issues to attract visitors -, and
- 2) the appearance of the mass media - starting with the radio - that could be used to promote museums. We can note that this period was also the beginning for museums to consider the economic equation of their business.

4.3.3 The Computer and Internet Revolution

Another switch in the museum paradigm began in the sixties when two phenomena in parallel - and inter-related - appeared:

- 1) computerised systems (and particularly network systems) started to appear and integrate all layers of the society, including museums (Marty, 2009).
- 2) Modern art and specifically digital and interactive art began to integrate museums around the world. The technology was finally able to provide a more interactive experience in museums, although the same questions as earlier in the century remained and divided the community.

Since the late eighties, we can certainly see a new step in technology integration within museums due to recent network technologies. Hardware networks were used in museums earlier; however, the raising of the Internet and particularly the web, followed by social networks in the early years of two-thousands had and still have a considerable impact on the museum experience approach. Visitor-centric, visitor-focus and later personalised experiences are some of the critical elements of the modern museum experience (Anderson, 2004).

4.3.4 A Continuous Quest

The history of museums in the western world shows us that since the early twentieth century, museums have started to experiment with media and technologies in a continuous quest to adapt to the always-changing society as well as for scientific questioning regarding the role of museums.

It is interesting to note that most of the questions related to technologies and their integration in museums have always been similar over the past century, though different in the detail technicality they are similar in their underlying fundamental questioning.

4.4 Drivers of Change

The dilemma between the fast technology development pace that continuously keep changing and the nature of a museum with its scientific approach that needs time to analyse information before integrating it consistently, is also a constant between museums across the century, even more, valid for modern museums.

We have identified four areas where museums are trying innovative ways to improve their experiences for the audience, namely: space confinement, context setting and design and finally sensorial experience. In the following sections, we will describe each of these areas in order to understand their origins as well as their related questioning in today museums.

4.4.1 Technologies and Museums

Museums have always experimented new supports, technologies and media to convey their message and attract a wider audience (Mandelli, 2012). However, the conclusions of those experimentations have always been very controversial in the museum and academic communities. Studies by (Griffiths, 2003) and others are going back as far as the late nineteenth century or early twentieth century. They are showing us how museums have experimented with new media and technologies at every major step of recent history, including radio, cinema or television.

Since the beginning of the cross-path between museums and the media and technology worlds, museums have always been on a cliff regarding their social role. Although most actors agree that museums should remain in a scientific and educational path with a clear social and moral responsibility toward the society, these fundamental cornerstones have been regularly challenged over the twentieth century with new media interaction and technologies integration sometimes to the limit of pure entertainment:

“The discursive oppositions between science and spectacle, information and entertainment, and passive and interactive spectators first articulated in relation to these visual technologies one hundred years ago have repeatedly resurfaced in contemporary debates over multimedia exhibits in public museums” (Griffiths, 2003)

The modern society and its media are sometimes blurring the lines between a particularly rigorous and scientific approach of museums and its permanent need of excitement, new technology and amazement. Museums are usually perceived as a reliable source of authority and expertise in their areas, whereas “edutainment” events or exhibitions are usually

oversimplifying the underlying message to make it more accessible, very often personalised and more importantly more enjoyable (Mans, 2011). Therefore, it is easy to understand that museums could also endanger themselves by going too far and ultimately losing their social authority.

4.4.2 Space Confinement

Museums are historically, and at first, a physical place where the museumgoers are coming to discover, to learn and to get a unique experience. The geographical location of the museum is a vital element of the experience and often an advantage for a museum, such as those in historical buildings, but it is also at the same time a physical restriction for the visitor: one must be able to dedicate some time and to come to the location to experience the visit:

"For many centuries museums were influenced by some very specific European traditions of mnemonics and spatial philosophy. Consequently, they had grown to be highly singular, framed places. They were part of the world, but at the same time removed from it. [...] Consequently, the 'visit event' had traditionally been a framed experience, both in space and in time. A museum was something you went to, with a threshold that marked its separation from the every day and that demarcated where these new forms of spatial production would begin" (Parry, 2007)

We could say that it is like going to a sacred place, such as a church, where the visitor decides to enter and take a distance from the world to have a sort of spiritual experience, an experience disconnected from the day to day world.

Since the beginning of mass media, museums have been trying different experiences to close the physical gap between the potential visitor and the actual physical place of the museum:

whether it is radio programs, television shows or advertisement. The significant change, however, started with the coming of computer network systems and especially with the democratisation of the Internet. Museums have now ways to bring their resources and part of their experience to the not-yet visitors through the digital environment. Not only they can create a new virtual experience, but as relevant, museums can reach a new public both online as well as invite them to a physical experience.

Although the Internet has the capability of bringing a large part of the museum experience to the public, economic and business questions as well as sociological issues are now related questions raised by the potential of these new technologies.

4.4.3 Setting design and contextualization

Due to their historical roots that we discussed earlier, museums have started as collections of objects displayed to the public. The initial objective of modern museology to democratise museums in the nineteenth century shown its limitations due to the fact that collections were most of the time created by academics and remained in their concept very elitists, requiring a high level of education to understand the background of one artefact. By the early twentieth century, curators started to propose different experimentation in order to enlarge the democratization of museums. Their work can generally be described into three areas, as explained in the next sections.

4.4.3.1 Quantity

It was very traditional for a museum to display as much as possible artefacts, to the risk to overload the museum and ultimately to lose the visitor into too much information or incoherent scenography.

In 1907, American Museum of Natural History (AMNH) President H. C. Bumpus complained that the museum visitors “became quite lost in the maze of exhibited material, and losing alike both points of the compass and sequence of theme, drifts about a mental derelict”⁴. Despite the early century questioning, this is still a criticism we can further find in recent years (Hein, 1998).

4.4.3.2 Design

Display cases, labels, captions and other traditional parts of museum exhibitions have also been under scrutiny since the beginning of the twentieth century⁵, and many experiments have been running since then.

4.4.3.3 Context

As mentioned above, collections of artefacts used to run with little to no contextual information as a simple series of objects, therefore, requiring visitors to have a good knowledge of the exhibition, its historical or geographical context. Exhibitions focusing on the number of artefacts are working against a large democratisation and education of the visitors, which are the fundamental role of a museum.

For example, in 1903, British curator F.A. Bather argued that “even when there is nothing strikingly incongruous or offensive in the manner of the exhibition, the mere removal of objects from their natural environment places them at a disadvantage.”⁶. Contextualization of artefacts by adding information about their natural environment or background history has since then become a regular discussion for curators and constant research for academics.

⁴ H.C. Bumpus, "A Contribution to the Discussion on Museum Cases," *MJ*, vol. 6, no. 9 (March 1907): 299.

⁵ A.B. Meyer, "The Structure, Position, and Illumination of Museum Cases," *MJ*, vol. 6, no. 7 (January 1907): 237.

⁶ Bather, "Museum's Association," p. 81

4.4.4 Sensorial Experience

In the early twentieth century, remarkable museums started to experiment with more interactive systems to allow their visitors to get in touch with some piece of art. For example, in 1901, the Metropolitan Museum of Art in New York City allowed their visitors to turn the pages of an art book through an ingenious system in the display case⁷. Over the century new experimentations took place in museums from North America and Europe until computers and networks systems became widely available by the end of the century.

"an hour's worth of teaching would not get so much information into the mind of the child as he would get by finding out the information for himself," one curator said as early as 1905⁸.

In modern museums, interactive systems are obviously in all curator minds as one way to modernise their exhibition with new technologies such as interactive tablets, movement sensors or even face detection to allow the visitor to get a sensation of more personal experience with the artefact.

This is still a field in exploration with many experiments running around the world, but seldom some significant data analysis on all those systems have been running. Chapter 6 will propose a possible framework to analyse and classify those systems in a systematic approach.

4.5 Conclusions

Following artists, museums have always looked at technologies as a possible way to increase their role and social impact for their promise to democratise knowledge as well as for education.

The economic aspect has also added pressure on the museum to develop and to boost their attendance and reconnaissance.

⁷ F.A. Bather, "The Museums of New York State," MJ, vol. 1, no. 3 (September 1901): 73

⁸ "Discussion," MJ, vol. 5, no. 4 (October 1905): 118

Over the past century, museum communities have extended experimentations with all sorts of technologies and processes. Although some have been proven to be very successful in a specific environment, it is still difficult to have a holistic under analysis to allow some new type of research. One of the works we would like to develop in the near future is a research platform to allow museums and academics to gather a large number of technologies experimentations around the world, being able to analyse the type of technology, the context or sociological impact, etc.

Following the past trends, we believe that there are especially two directions that museums can develop in the future, besides existing technology integration such as remote application, social networking, etc. The first one is related to virtual reality and augmented reality, a space where the technology is becoming mature enough to be easily used by large public; the second is more funded on the participation of certain publics to be more proactive in the museum development - this is how we see some fabrication laboratory developing within some museums or remixing experiences such as the one we will discuss in chapter 6.

CHAPTER V

The Spectrum of Interactivity

A Multivariate Analysis Framework for Interactive Apparatus

5.1 Introduction

Interactive apparatus and technologies have been used in museums for more than thirty years. Results of experiments have shown a high interest for all stakeholders, and it is now clearly becoming a trend for most museums to try to integrate them in one way or another. However, even after several decades of experimentation, research and analysis, there is little literature on a type of classification that could help to understand the nature of interactivity of each apparatus in museums.

It is now well recognized that interactivity and social interactions are essential to museum experience (Heath, 2005). It has already experimented for many years in science and technology museums around the world where the purpose of most of the exhibits are by nature to interact with the visitor and provide a tangible user experience (Stevens & Martell, 2003).

However, art museums are not always providing much interactivity between visitors and exhibited artwork. They still are, in their majority, considered as a sanctuary to display and admire artworks. We can also clearly note some changes in modern art museums where some artworks can be interactive by creation - as created by the artist - and react to the public actions, they are clearly an isolated world in art museums in general, somehow a bridge between science museums and art museums: this interactivity is brought and supported by the artwork itself rather than part of a more extensive approach at a museum scale.

For many years, museums have been trying to fight the decrease of visitors and their low interaction with exhibits with two significant approaches (Bradburne, 2001): 1) large popular exhibitions and 2) new modern buildings. Museums still use these two expensive approaches, but there is now a new trend to invest massively in interactive and digital technologies. Interactive technologies have been experimented and, in some cases, implemented permanently in art museums in the last ten years. Visitors not only can see and watch artwork but can often

“touch” - usually virtually - and interact with them as well (D Vom Lehn, Heath, & Hindmarsh, 2005).

All sorts of digital technologies have been deployed for museums: robots, video and audio installation, smart card or mobile computing, interactive touchscreen, 3D projection and visual effects, and more - All of those technologies powered by computer. Early experiences were usually with limited “natural” interaction for the visitors due to the limited processing power or the limited space -or large size of computers. Recent experiments are usually more focus on the importance of the design and a “natural” user interaction powered by ubiquitous computing (Weiser, 1994), or disappearing computing.

Furthermore, published papers and studies related to museums and interactivity have vastly covered the technological area, visitor behaviour and social behaviour (Dirk Vom Lehn, Heath, & Hindmarsh, 2001).

In this chapter, we will review past experimentations and research, and we will propose an initial framework to classified interactive apparatus used in museums as a framework to better understand the nature of each interactive apparatus and to allow some comparison in the future. It is still a vast investigation field with much research needed around the interactivity and technology in museums but also to stimulate new creativity and innovate for new experiences in museums.

5.2 Multivariate Analysis Framework for Interactive Apparatus

As we have mentioned in Chapter 2, interactivity is a complex concept that can be approached through different angles and different theories. How can we resume multiple approaches into one framework? This is the question that we are proposing to answer in this chapter by

introducing a multivariate framework that can cover the essential aspects of an interactive apparatus.

We have, in chapter 2, defined interactivity as a relational property of an apparatus with a real-time and dynamic nature. Although this attribute is activated once an interactor is willing to interact with the apparatus, we have stated that interactivity is a phenomenon that can be studied independently (Svanaes, 2000). The interactivity attribute is a property of the apparatus by itself as Jean-Louis Weissberg mentioned. The property is not activated without an external trigger; however, the interactive property exists on its own; it is not dependent on the external activity. The interactivity has been built-in into the apparatus by the authors; therefore, it has been conceived from the beginning and exists as a potential attribute.

In this section, we will try to define a semantic classification or taxonomy regarding the interactivity apparatus in museums. It will allow us to cover interactive systems used or experimented in museums as of today and give a global approach to classify them with some simple criteria.

Over our literature review, we have tried to establish a state of the art of interactive apparatus in museums - whether it is an interactive artwork or part of a design workflow - to give a more global perspective on this field as well as some keys to classify research. Following our previous chapters, we are in this chapter, proposing a tool to classify interactive apparatus integrating several concepts. Those concepts derived from our work from chapter 2 and is currently encompassing four main areas: 1) the Modes of Interactivity, 2) Analysis of all Inputs and Outputs, 3) the Social Interaction Level and finally 4) a Museology taxonomy. They are all detailed in the following subsections of this chapter.

M.A.F.I.A.⁹ is the acronym based on the name of the framework presented here, and we would like to note that it is representing the values of a particular movement of hacking as discussed in chapter 4 and presented by (Himanen, 2001) (Parker, 1976) and (Levy, 2010): values to oppose the institutional power, to transform the perspective and to subvert the meaning of words - as much as for playing and enjoyment as to stimulate reactions.

However, we are not, in any way, supporting the illegal organisation that took - illegally, of course - our acronym for their activities.

5.2.1 Modes of Interactivity

The first section of the framework is defining the modes of interactivity. Following our discussion in chapter 2 - as well as based on our experimentation discussed later in chapter 6 - we are proposing here to define the interactivity through its interface (or medium) as well as its level of coherence. We are discussing these two modes in the following subsections.

5.2.1.1 Medium

This mode of interactivity is describing the main type of interfaces an apparatus presents toward the interactor, and it can include:

- **DIGITAL** - This mode is describing any interactive apparatuses which are interacting with the interactor in a digital environment without any direct link with the physical world.
- **AUGMENTATIVE** - This mode describes an interactive apparatus that provides, to the interactor's input, an output that will integrate the surrounding physical world. An

⁹ Multivariate Analysis Framework for Interactive Apparatus

example for this case can be described with an interactive video projection or video mapping apparatus.

- PARTICIPATIVE - This mode describes an interactive apparatus that evolves in time based on successive interactors input; it integrates the user's inputs into its outputs.
- SOCIAL - This mode describes an interactive apparatus that mainly stimulates social interactions between interactors and/or visitors.

It is important to highlight that these interfaces are not exclusive; indeed, an interactive apparatus can present several interfaces to the interactor, either at the same time or at different periods of the interaction.

5.2.1.2 Level of Coherence

The level of coherence is describing the coherence of the interaction between the interactive apparatus and the interactor. As we discussed in chapter 2.1.1.2, (Smuts, 2009) compares the interactivity with the human-to-human dialogue and he is mentioning three different possible states: random discussion - no coherence possible -, responsive discussion - simply an echo - and a normal dialogue and finally an intelligent dialogue where there is no control from one participant to the other. Although he is excluding the random and responsive levels, we are, as we mentioned earlier as well, integrating them as possible interactivity levels. Therefore, our level of coherence can be described as follows:

- NONE - or level 0, this level is where there is no interactive attribute within the apparatus.

- RANDOM - or level 1, this level describes an interactive apparatus that provides an apparent random output. This apparent random reaction of the apparatus is indeed interactive, although the interactor cannot make sense of it - at least during a certain time.
- RESPONSIVE - This mode describes an interactive apparatus that provides an output strictly proportional to the interactor's input. In this mode, the interactor is perfectly controlling the apparatus - within the freedom offered by the apparatus. The example of the television is typical of a simple case for this mode: the interactor is giving a command, through the remote control, and the television will, as expected, execute the command and delivers as output the requested order.
- INTELLIGENT - This mode describes an interactive apparatus that can create a notion of dialogue between the interactor and the apparatus. The apparatus is not reacting randomly and at the time, it is not controlled by the interactor. We could describe it as it looks like the apparatus has its intelligence. This is the mode describing the definition of interactivity by philosopher Aaron Smuts, that we described in chapter 2 (Smuts, 2009).

Regarding the three modes used in our framework for the level of coherence - random, responsive and intelligent - of an interactive apparatus we have decided to keep them as discrete representation, but we understand that it could be represented by a linear scale to give more granular options. However, a more granular scale would be at this stage too subjective since we have not yet been able to define a scientific way of calculating a number on a scale. This is something we could consider for future research.

5.2.2 Inputs and Outputs in a Sensory Representation

This section of the framework is helping us to identify the communication channels between the 2 actors of interactivity: on one side the human senses and body, on the other side, the computer-based system with its sensors - input or sensing devices -, and actuators - output or interpreting device.

In order to estimate the input and the output independently, we will evaluate each interactive apparatus with a grid of 2 columns: one corresponding to the sensing device and the other one to the interpreting device.

Although we are identifying the communication channels of the interactive apparatus - and not the human, we have decided to use the representation based on human senses in the grid rather than any notion of technology. Human senses are clearly identifiable, and their knowledge is stable - for the foreseeable future, whereas, it is evident that technology is permanently evolving and new technology is replacing old ones on a regular basis. It would be, therefore, very inconsistent with using an analysis grid with old terminology and outdated technology.

We can resume the Sensing Devices and Interpreting Devices of an interactive apparatus as follows:

- Inputs and Outputs of the interactive apparatus are analysed - not human senses,
- Inputs and Outputs are analysed independently,
- Inputs and Outputs are identified with the human sensory system representation.





Our analysis grid is then composed of three columns:




1. The human sense as a representation of an input or output for the interactive apparatus
- vision, hearing, touch, vestibular, proprioception, gustation and olfaction,

2. The column related to Sensing Devices: we are validating - or not - whether the interactive apparatus has some sort of sensing system to allow it to capture in the sense of the corresponding human sense.
3. The column related to Interpreting Devices: we are, like for the Sensing Devices, validating - or not - whether the interactive apparatus has some sort of actuating system to produce some external signal understandable by the corresponding human sense.

Each device is not limited to a specific technology, but they are rather attached to the fundamental function of the technology used. We cannot list all technologies possible for each case, but we can easily identify the major ones:

Table 1 - Sensory Representation table

	SENSING DEVICES (INPUT)	INTERPRETING DEVICES (OUTPUT)
VISION 	<ul style="list-style-type: none"> ● Camera, ● Infrared Sensor, ● Microsoft Kinect, ● ... 	<ul style="list-style-type: none"> ● Screen, ● Projection, ● Holography...
HEARING 	<ul style="list-style-type: none"> ● Microphone, ● noise sensor, ● ... 	<ul style="list-style-type: none"> ● Audio Speaker ● ...
TOUCH 	<ul style="list-style-type: none"> ● Touch screen, ● Capacitive or resistive touch sensor, ● ... 	<ul style="list-style-type: none"> ● Vibration system, ● Haptic game controller, ● ...
LOCATION 	<ul style="list-style-type: none"> ● Proximity sensor 	<ul style="list-style-type: none"> ● Movable platform, ● (*)

kinaesthetic 	<ul style="list-style-type: none"> ● Movement sensor ● Microsoft Kinect, ● ... 	<ul style="list-style-type: none"> ● Movable platform, ● (*)
GUSTATION 	(**)	(**)
OLFACTION 	(**)	(**)

(*): Some rare technologies can exist; however, it is not used in any interactive apparatus studied presently in our work.

(**): Gustation and olfaction are senses where some technologies exist but are complex to control and implement. More importantly, these senses are still perceived by the public as private senses.

Based on the analysis grid proposed above, we can then present any interactive apparatus with an easy to understand graphical representation of its inputs and outputs functions. Not only it will help us to classify interactive apparatus by their inputs and outputs, but it will also help us to compare them and to understand their actions better.

In the future, we hope to be able to establish a standard mapping system between the sensing devices and interpreting devices based on this analysis grid. It might help us better understand what are the most common trends and the best practices for interactivity with the technology? The technology used as well as, over time, measure changes and evolution of their usage.

5.2.3 Social Interaction Scale

In her book “The Participatory Museum” (Simon, 2010), Nina Simon is proposing a scale to measure the level of social interaction for a specific installation in a museum. She called this social interaction scale the “Me to We”, and she defines it as shown in the following figure.

The scale is defined by the author with five stages: going from no interaction at all to a full social interaction among the visitors. This scale has been defined to evaluate visitors and interactors actions with an exhibit - interactive or not - and as such, it is meant for audience engagement evaluation.

We must also point out that the concept of social interaction is here defined as a possibility to create human to human interactions, whether it is by direct interactions or through some social systems such as social networks.

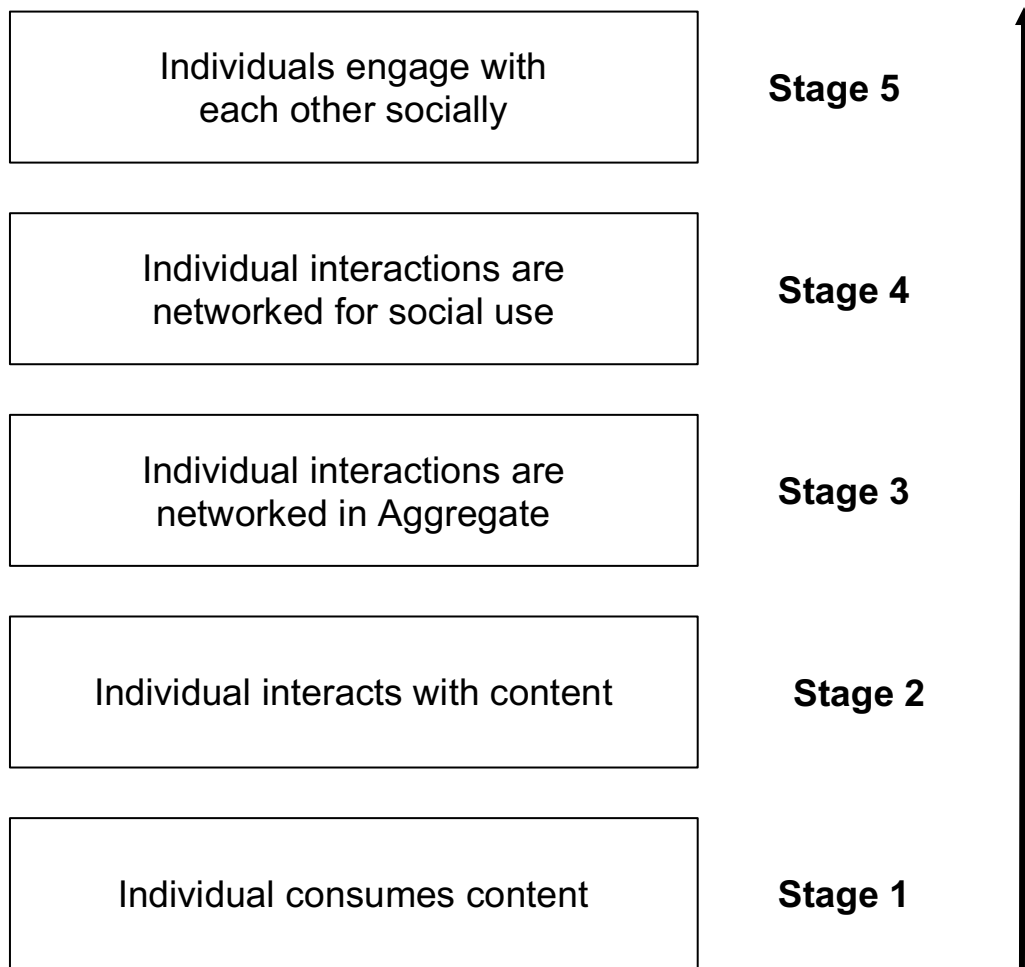


Figure 4 - Figure 1 - “Me to We” stages, from “The Participatory Museum”, Nina Simon

However, we have decided to integrate this scale into our work because we believe it is also interesting to be able to evaluate the potential of social interaction of an interactive apparatus. As we mentioned earlier in chapters 2 and 3, we are interested in the intentions of an interactive apparatus, its attributes, whether they are or not actually triggered or used by an interactor. Moreover, by integrating this scale into our analysis framework at the interactive apparatus level, we are opening the future possibility to compare and measure the intentions with the actual social engagement of the interactor.

5.2.3.1 Individual Consumes Content

The first level of this Social Interaction Scale represents an individual passively observing an apparatus - interactive or not - or an artwork. It is the example of a visitor in a museum watching a painting: the artwork is not interactive in this case, and there is no interaction between the exhibit and the visitor, beside a possible emotional trigger to the visitor.

In the context of our work, in the presence of an interactive apparatus, the visitor will simply observe the apparatus but will reject - consciously or not - any interaction. Since we are analysing interactive apparatus attributes as potential properties, this stage will not appear as part of our results.

Although this stage is not engaging any interactivity between the visitor and the apparatus and will therefore not be used in the analysis of interactive apparatus, it is important to keep it in our analysis framework for future research related to the audience engagement. This stage will allow us to measure visitors not engaging with the apparatus for whatever reason it could be.

5.2.3.2 Individual Interacts with Content

The second level of the scale is describing a one-to-one interactivity stage where the interactor interacts alone with the interactive apparatus. In the context of the original publication, there could be several reasons to encounter this stage:

1. The interactor is alone, and he is, therefore, interacting with the interactive apparatus only - no other option is possible beside waiting for more potential interactors to come in.
2. The interactor is not willing to engage in a larger social interaction and decides to interact only with the interactive apparatus and at the same time rejecting any potential trigger for broader social interaction.

3. The interactive apparatus is by design only mono-use, and therefore, only one person can actually interact with it at a specific moment. It is a one-to-one interaction.

In the context of our work, since we are focusing our Interactivity Analysis Framework on the understanding of the apparatus itself and its intrinsic attributes, we are not considering the position of the interactor but only the intent of the interactive apparatus.

5.2.3.3 Individual Interactions are Networked in Aggregate

The third level of the scale encompass the previous level described in 5.2.3.2 “Individual Interacts with Content” where the interactive apparatus is providing a one-to-one interactivity. Instead of only interacting with the interactor, the interactive apparatus is now capable to understand each of its interaction and keep some information about it in an aggregated dataset. Not only the interactive apparatus is collecting information about its human counterpart but the most important part of this stage is an aggregated restitution of these interactions.

At this stage, the interactive apparatus is reflecting back, in near real-time, an aggregation of data, not attributed to any individual but globally calculated by its own algorithms. This aggregated information is meant to be understandable by human beings and its ultimate goal is to generate visitors and interactors to relate to this information. A simple example could be described as a system that would give the average score of all the interactors for a specific interactive apparatus; it will help one interactor to understand where he or she stands and ultimately be able to discuss it with his or her peers around.

As mentioned earlier, our framework will consider an interactive apparatus to be at this stage if it can provide the visitors and interactors with some aggregated information of all - or part - of the interactions. The potential of creating a social link is something that would interest the audience engagement, which is not part of our work.

5.2.3.4 Individual Interactions are Networked for Social Use

The fourth level of the scale is very similar to the previous stage described in section 5.2.3.3. The only difference between these two stages is in the restitution mode of the data collected for each interactor. Although in the previous stage, the interactive apparatus was restituting aggregated information only - and therefore, no individual identification is possible - in the current stage, data are attached to the individual interactor.

This stage is meant to encourage social interaction between interactors but this time based on their personal preferences and result of their interaction with the interactive apparatus. The difference with stage 3 is that social engagement is more demanding in the sense that the interactor must be willing to share his or her results of the interaction publicly.

In our work, as we are considering only the interactive apparatus in its intent and potential interactivity attributes, we are also able to make the distinction between the third stage and the current stage. Indeed, we can clearly separate interactive apparatuses by identifying how the result of their interaction with the interactors is shared with the public: either they are aggregated results or they are identifiable by interactor.

Although the difference between stage three and four could be considered as small since it is only different by the representing output modes, we believe it is worth to keep them in separate levels. Indeed, the audience engagement can present highly different typologies whether the interactive apparatus presents an aggregated result - as simple as an average of some activities - or if it identifies individual interactors and encourages them to bear their opinion and activity. Finally, it is worth mentioning that both stage 3 and 4 can be both considered as a participative experience since actions of interactors have an influence in time on the apparatus representation.

5.2.3.5 Individuals Engage with Each Other Socially

The fifth and last level of the scale is changing the type of interaction from an individual to a more collaborative approach. Compared to previous third and fourth levels where the input of the interactive apparatus was toward individual interactors, this stage is changing the way an interactive apparatus integrates its inputs and/or delivers its outputs.

In the approach of the author with the audience engagement in mind, this stage is to highlight interactive apparatuses with high collective engagement. The objective is to create social interaction within the interactivity, therefore engaging the interactors in a collaborative work toward the objective(s) of the apparatus. For example, interactors would have to cooperate to build the final piece of the interactive apparatus.

In this case, the interactivity is conceived to be collective and/or participative. For a museum, it is an attractive paradigm to see your visitors engaging with each other by interacting with the presented exhibit.

Within the context of our work, this ultimate stage can be describing interactive apparatuses which require collective inputs - as in multiple interactors will be needed to achieve the apparatus goals. We will also add the criteria from the third and fourth stages of this scale: outputs of the interactive apparatus are also established to encourage social interactions among the interactors.

5.2.4 Museology Taxonomy

The last part of our Interactivity Analysis Framework is focusing on one of the contexts of this research: museums. Indeed, as we are analysing interactive apparatus within the context of museum, it is important as well to understand how we could propose a high-level classification based specifically on museum activities and development.

We have identified five categories to classify interactive apparatus with a museum terminology.

These five categories are:

1. Personalized Tour-Guide
2. Gamification and Entertainment
3. Virtual Environments
4. Social Interaction
5. Participation

In this section, we will discuss each one of these categories, and we will use them later in chapter 6 for our study case as part of our framework. As we are describing these categories, we will as well identify some of their limitations in the context of museums.

5.2.4.1 Personalized Tour-Guide

This is probably the easiest category to approach and understand since it is trying to enhance or sometimes simply copy or mimic what museums have already provided for years to their visitors: a tour guide (Thrun & Bennewitz, 1999) and (Hage, Stash, Wang, & Aroyo, 2010). This category is about re-imagining, through technology, an existing and traditional and often pre-defined on-site tour of a museum.

Tour-guide can be described with two separate goals:

1. To Guide the visitor through the museum or a part of it to see artworks - or any kind of exhibits - in a certain predefined order,
2. and secondly provide details information and metadata related to artwork to highlight them to the visitor and allow the visitor to have a better understanding of the artwork, its context and environment.

Traditional tour-guide systems are by nature generic and are only proposing a few options to choose from, but they do not have the capacity to understand the visitor interests or need and to adapt to them.

The use of technology in some tour-guide systems is trying to solve these limitations. It can allow a museum to provide activities that would be impossible in a traditional tour-guide such as personalization of the tour based on the visitor's interests. The personalisation can be based either on the visitor taste that can be pre-defined beforehand (Hage et al., 2010) or it could also be generated during the visit based on what the visitor is seeing, adapting the tour to fit the visitor needs (Burgard, Cremers, & Fox, 1998).

As much as these systems could be interesting for museums, there are risks linked to them as well. Indeed, we can identify some limitations to these types of interactive apparatus in museums, such as :

1. Personalization is always subjective and bias to the algorithm used and the creator/developer perspectives. The proposed tour might ultimately not correspond to what the visitor wished, even when he was the one to give his own preferences.
2. Personalizing based on preferences can tend to limit the tour to what the visitor already knows and expect but can rarely provide a “surprising effect” that a visitor could have by wandering around on his own and suddenly discovering an artwork that he will never expect to enjoy and therefore opening his spectrum of knowledge.

5.2.4.2 Gamification and Entertainment

“Gamification is the application of game-design elements and game principles in non-game contexts” (Robson, Plangger, Kietzmann, McCarthy, & Pitt, 2015)

The second category is covering a modern educational and pedagogical paradigm: transform a serious or complex topic into a game - or at least adding to it a game mechanic. In this type of system, the objective is to encourage to learn and to teach the interactor through a game mechanic. The fundamental bet of this approach is to bring more engagement and fun to the interactor than a traditional learning process.

Gamification is the use of play principles and game mechanics to engage users in solving problems and learn through this process. Gamification is applied to many business areas; whether it is to improve user engagement or learning outcomes, it is a well-known methodology that cultural and educational institutes are also integrating into their tools for mediation.

Museums are potentially good candidates for gamification since they provide large spaces with tremendous valuable information to assimilate for visitors (Dini, Paternò, & Santoro, 2007) and (Cabrera, Frutos, & Stoica, 2005).

Gamification has always been controversial among academics and cultural institutes. Although this paradigm can have a very positive effect, it also has some limitations and risks, particularly for a museum. We have identified at least two major risks:

1. A risk on the content: the engagement in the game can be so intense for visitors that the game itself might actually have a too deep layer between the visitor and the artwork message. The visitor could have a very good experience but miss the museum content value.
2. A risk on the population: not all visitors are ready to engage in a game to discover a museum, it might be too intrusive or too engaging for some of them. Instead of engaging the visitor, it might actually repel it.

5.2.4.3 Virtual Environments

“Virtual museum, a collection of digitally recorded images, sound files, text documents, and other data of historical, scientific, or cultural interest that are accessed through electronic media.” Encyclopaedia Britannica.

A virtual museum is usually considered as an online museum, available through the Internet on a website or a dedicated application, such as virtual reality glasses. In the context of our research, we are considering “Virtual Environments” as digital environments either remotely accessible or any sort of digitally immersive environments; whether they are related to the physical environment of the museum or different experience, they are representing the museum in a digital environment.

Beside some exceptional cases, most virtual museums stand against physical museums, in the sense that museums are struggling - besides some exceptions - to find an approach that would propose a new experience to interactors without cannibalizing their physical environment and business model. Museums have usually developed their own institutional website to provide both practical and artistic information about their physical place and to help potential visitors to prepare their visit within the physical building of a museum. However, some museums went further to develop their own museum online where online visitors can see not only what is available on the physical museum but often also what is not visible within the museum building but only available in the museum storage (Aroyo et al., 2007). Museums usually have a large number of artworks, and not all can be displayed in the limited space of museums but can have a “second life” online and virtual visitors a chance to see them.

There are also some very specific cases where museums exist only online, or others are meta-museums or museum of museums: online museum gathering artwork from several physical museums: gathering artworks from around the world at a click of the mouse.

Finally, we identified as well some museums providing some after-visit experience for their visitors. Online, they can find traces of their visits, some analysis and suggestions for a future visit (Hage et al., 2010).

Within the context of our work, we will also consider a virtual environment a physical space that is purposely creating its own environment, disconnected from the museum physical environment - although it can be related obviously. An example of such an environment could be a temporary dedicated “room” for an experience not directly connected to the rest of the museum.

As in the previous sections, we can also identify some limitations and risks with virtual environments in museum institutions, such as:

1. Giving access to a large quantity of artwork online can create confusion for some visitors: they might feel lost in an ocean of artworks, and it might create a high noise-content ratio. Too much content might also damage the underlying museum message and image.
2. Visiting a museum online is a very different experience than a physical visit, and you cannot expect the visitor to have the same experience as it would be for a traditional physical visit. For some artworks, it might be difficult to give a good virtual representation of it due to their nature and the limitations of existing technology - such as 3D representation.
3. Existing virtual environments for museums are most of them proposing an individual visit without integrating that social interaction. Museums have recognised that it is also an essential part of a museum visit, as we mentioned earlier in this chapter on 5.2.3 on the Social Interaction Scale.

5.2.4.4 Social Interaction

Social interactions are part of our human nature and very often a source of engagement, emotion or even conflict. As we mentioned earlier, social interactions are a core part of the experience at a museum, whether it is as simple as people knowing each other - e.g. a family - or people interacting with each other for the first time. Therefore, encouraging these types of interactions with interactive apparatuses is a normal path for museums looking to enrich their visitors' experience. Social interaction is very often and easily generated through gamification (Heath, 2005) and (Dini et al., 2007); therefore, these two categories are often found together in interactive apparatuses, but they are not inherently linked.

Although social interactions are part of most museums' objectives, we can also identify a few limitations and risks, such as:

1. By creating too many social interactions, an interactive apparatus could actually distract the interactors instead of encouraging them to acquire more knowledge and learning experiences from the content of an exhibit of the museum.
2. Social interactions are easy to stimulate with people knowing each other but can be extremely hard to create or even generate bad experiences for people unknown to each other. The museum would have to be very careful about giving alternatives to social interactions.

5.2.4.5 Participation

The participation category can be defined by an interactive apparatus reacting to its interactor's behaviour and modifying somehow its own behaviour based on the interactors' input. We identified two types of participation: individual and collective. In a way we could say that the interactor is to a certain extent "part of the exhibit" or at least its behaviour has an impact on

the exhibit presentation either in its visual or audio representation at least (D Vom Lehn et al., 2005), (D vom Lehn, Heath, & Hindmarsh, 2002) and (Stevens & Martell, 2003). This mode of creation tends to be very popular in modern art exhibitions where the artist creates an artwork that continuously evolves in time based on the behaviour of the interactors.

We chose the term participation rather than collaborative since we believe collaborative encompass a certain degree of freedom for the interactor, however, interactive apparatus, by their technological limitation and/or the creative decisions, are always limiting the options of actions for the interactors. This is why we are considering the interactor as participating with the interactive apparatus.

By definition, this type of apparatus is not fully controlled since it relies in part on the interactors. Such apparatus has, in its own roots, some risks, such as:

1. The museum might be at risk with these types of exhibition in the sense that visitors could use the apparatus in ways not originally imagined by the artists/creators of the apparatus. As we discussed in chapter 3, hacking such type of exhibits is in the human nature: we are constantly trying to understand how something works and how we can use it to our advantages in ways that were not originally planned. It could be like giving a wall for visitors to write whatever they want about a specific topic or exhibition: the museum could end up creating unwanted controversy - or even illegal issues - but it could also become an incredible participative experience - one example will be given later in chapter 6 with one of our experimentation.
2. As mentioned in the previous category “Social Interaction”, not all visitors might be willing to enter into a sort of collaboration with the museum or be part of a subset of an exhibit.

5.2.5 Technology Survey

Besides the proposed classification above, we also integrate an overall survey on technology to identify major types of systems used in museums. Added to the taxonomy, it could be seen as a two-dimensional matrix to help identify and understand interactivity and its related technologies. We are not trying to define the details of technology but rather the key components of an interactive system.

The following set of technologies have been identified:

- **Audio** – whenever sound is playing a role in the interactivity. It can be music, voice or sounds.
- **Video** – any type of video projection (with projectors, screens, TV...) whenever they are part of the interactive apparatus.
- **Smart Tags** – any tagging technologies - such as RFID and NFC - that helps to identify, track or customize an interactive experience.
- **Touchscreen** – user interface to allow the visitor to control or interact with the system. They can be fixed or mobile.
- **Augmented Reality** – any system allowing to add meta information
- **Intelligent Robot** – a computing system interacting with visitors - often used for personalized tour-guide.
- **Location awareness** – the system is using the visitor location or its own local location to provide specific interaction or information.
- **Movement** – the system is using the visitor movements or its own movements to interact with the visitor.

This classification is a first attempt and can probably be fine-tuned in further research and collaboration. It is based on our personal experience and literature reviews on interactive

apparatus in museums. However, we must highlight that this is not an important part of our framework.

5.3 An Implementation of the Framework

Following the establishment of our analytical framework, we have then developed a tool to collect data related to an interactive apparatus and to give us the possibility to analyse and compare different apparatuses.

This tool is a web application which stores all the data into a database, lists and shows the details of the interactive apparatuses part of our study case (see chapter 6). The database is then integrated with the statistic software RStudio (based on R application) to generate charts and graphics for our analysis.

The web application is a published open-source software developed on top of other well-known open-source projects, including:

- NodeJS¹⁰ the JavaScript backend infrastructure based on the V8 Engine, as well as NPM¹¹ the NodeJS Package Manager.
- ExpressJS¹² a framework to develop web application as well as API,
- NeDB¹³, a simple file-based database compatible with MongoDB¹⁴ database. In this first stage of development, a file-based database is more than enough, but in the long term, we will migrate the database to a full-fledged document-based distributed MongoDB database to handle more data and queries.

¹⁰ <https://nodejs.org/>

¹¹ <https://www.npmjs.com/>

¹² <https://expressjs.com/>

¹³ <https://github.com/louischatriot/nedb/>

¹⁴ <https://www.mongodb.com/>

- Pug¹⁵ is a simple templating engine for Javascript, it is the default template engine for ExpressJS and it can be used both on client and server-side projects simultaneously.
- Bootstrap¹⁶ is a popular CSS - Cascading Style Sheets - framework developed by Twitter. We used a specific version of Bootstrap 4 that integrate the Material Design principles and user-interface from Google¹⁷.

The code developed is available in Appendix 1 as well as its latest version is published on GitHub¹⁸, a platform to share source code.

The objective is to publish this application online freely available for researchers, academics or the general public. Not only the source code is available but we intend to publish it online so the application and the current database are freely browsable for everyone and hopefully we can attract new collaborations to further develop this framework.

Currently, the application provides the following features:

- View the list of interactive apparatus,
- View the details of each interactive apparatus,
- Insert a new interactive apparatus,
- Search through several criteria, including:
 - Search by keywords: keywords are currently search in the following fields of the database: the name, the year, the place, the country, the type of place, type of event, the modes of interactivity and the description.
 - Search specific field,
 - Pagination,

¹⁵ <https://pugjs.org/>

¹⁶ <https://fezvrasta.github.io/bootstrap-material-design/>

¹⁷ <https://material.io/>

¹⁸ <https://www.github.com/>

- Sorting by date only.
- Download the full database as a JSON file for further manipulation.

5.3.1 Data Acquisition

The web application provides a complete form to insert new interactive apparatus inside the database and add it to the global database and list it on the web application as well. This web form is divided into five main areas, covering all the aspects of the framework described earlier in this chapter.

The figure below shows the web form as it is available in the application:

Interactivity Analysis Framework
Search

Interactive Apparatus

Enter all the required information based on observation or interview with the author(s).

1. Apparatus

or Installation are interactive "dispositif" (or systems)...

Name

URL

Place --- Type ---

Type of event Year

City Country

Description

Technologies

Image link

License

Authors

2. Modes of Interactivity

MEDIUM

DIGITAL

AUGMENTATIVE

SOCIAL

PARTICIPATIVE

LEVELS

RANDOM- level 1

RESPONSIVE- level 2

INTELLIGENT- level 3

3. I/O

Interactive Apparatus have some properties to understand or express to some human senses, they are the input and output of the apparatus to communicate.

	INPUT	OUTPUT
Visual <small>Apparatus provides visual information/interactions.</small>	<input type="checkbox"/>	<input type="checkbox"/>
Audio	<input type="checkbox"/>	<input type="checkbox"/>
Touch	<input type="checkbox"/>	<input type="checkbox"/>
Spatial Orientation Vestibular <small>sense of balance and spatial orientation</small>	<input type="checkbox"/>	<input type="checkbox"/>
Movement Proprioception <small>or kinesthetic: sense of self-movement and body position</small>	<input type="checkbox"/>	<input type="checkbox"/>
Gustatif	<input type="checkbox"/>	<input type="checkbox"/>
Olfactif	<input type="checkbox"/>	<input type="checkbox"/>

4. Social Interaction

Social Interaction Design framework is inspired from Nina Simons in her book "The Participatory Museum" (ref...)

Individual Consumer

Individual Interactor

Individual Interactions Mapped

Interaction-based Community

Global Social Engagement

5. Museology Taxonomy

This section is only relevant for interactive apparatus available in museums.

Guided Tour
Apparatus is designed to guide and/or give information to the visitor.

Gamification
Apparatus provides some sort of game mechanic.

Virtual Museum
Apparatus includes AR/VR or Remote access (such as a website)

Social Interaction
Apparatus is designed to encourage social interactions between visitors.

Collective Participation
Apparatus is evolving with input from visitors.

Figure 5 - Web form to enter new interactive apparatus in the database

5.3.1.1 General Information

The web form starts with some general information about the apparatus we wish to insert. That information is important in order to have some basic understanding of the apparatus, including the following:

- The name of the apparatus: most of the time, the authors, will give a specific name or title to their creation or at least a simple description.
- URL: it is the link to the original web page describing and presenting the apparatus, if it exists.
- Place: the location where the apparatus has been observed and experimented. With our study case, all interactive apparatuses have been within museums around the world, however, it is not a requirement at all.
- Type of Public Space: a list of typical public spaces where interactive apparatus could be setup. It helps us to create categories of public spaces. It is worth to note again that, all our study cases are only part of museums. This list includes: Museum, Gallery, Library, Street, Exhibition, School, Church. Obviously, this list could be easily extended if needed, we only listed those one due to our personal experiences in the past.
- Type of Event: in case the interactive apparatus has been created through a specific event it is worth noting it but it is not a requirement. In the case of this work, all our interactive apparatuses analysed have been created through a Museomix event.
- Year: the year the interactive apparatus has been created.
- City: the city where the interactive apparatus has been observed.
- Country: the country where the interactive apparatus has been observed.
- Description: a possible short description to understand what is the intent of the interactive apparatus described.

- Technologies: a comma-separated list of technologies used inside the interactive apparatus.
- Image link: whenever it is possible, a URL of a photo of the interactive apparatus. It is always better to have a visual to help the reader to understand the apparatus.
- License: whether it is a proprietary license or an open license. The majority of apparatuses in our study case are under an open-source licenses, however, this is not a requirement for an apparatus to be inserted in the framework.
- Authors: the name of all the authors of the interactive apparatus.

1. Apparatus
Apparatus or installation are interactive "dispositif" (or systems)...

Name _____

URL _____

Place _____ Type of Public Space _____

Type of event _____ Year _____

City _____ Country _____

Description _____

Technologies _____

Image link _____

License _____

Authors _____

Figure 6 - General information about an interactive apparatus

5.3.1.2 Modes of Interactivity

The second section of the web form to add a new interactive apparatus in the Interactivity Analysis Framework is about the Modes of Interactivity.

It includes elements described in section 5.2.1, namely:

MEDIUM - multiple-choices possible

- Digital
- Augmentative
- Social
- Participative

LEVEL of INTERACTIVITY

- Random
- Responsive
- Intelligent

2. Modes of Interactivity

MEDIUM	LEVELS
<input type="radio"/> DIGITAL	<input type="radio"/> RANDOM- level 1
<input type="radio"/> AUGMENTATIVE	<input type="radio"/> RESPONSIVE- level 2
<input type="radio"/> SOCIAL	<input type="radio"/> INTELLIGENT- level 3
<input type="radio"/> PARTICIPATIVE	

Figure 7 - Modes of Interactivity

5.3.1.3 Input / Output

The third section of the web form to add a new interactive apparatus in the Interactivity Analysis Framework is about I/O - Input/Output - and was described in section 5.2.2.

It is based on a representation of all the human senses in a double array to describe which senses are used in input of the interactive apparatus and which senses are used as output of the interactive apparatus. The list we selected is:

- **Visual:** as an input it can be through a camera, as an output it can be a display or a projector for example.
- **Audio;** as an input it can be through a microphone, as an output it can be through speakers.
- **Touch:** as an input it can be through a touch sensor or a touchscreen, as an output it can be through different materials or a robot harm for example.
- **Spatial Orientation** (based on the vestibular sense)
- **kinaesthetic** (based on the proprioception sense)
- **Gustatif**
- **Olfactif**

3. I/O

Interactive Apparatus have some properties to understand or express to some human senses, they are the input and output of the apparatus to communicate.







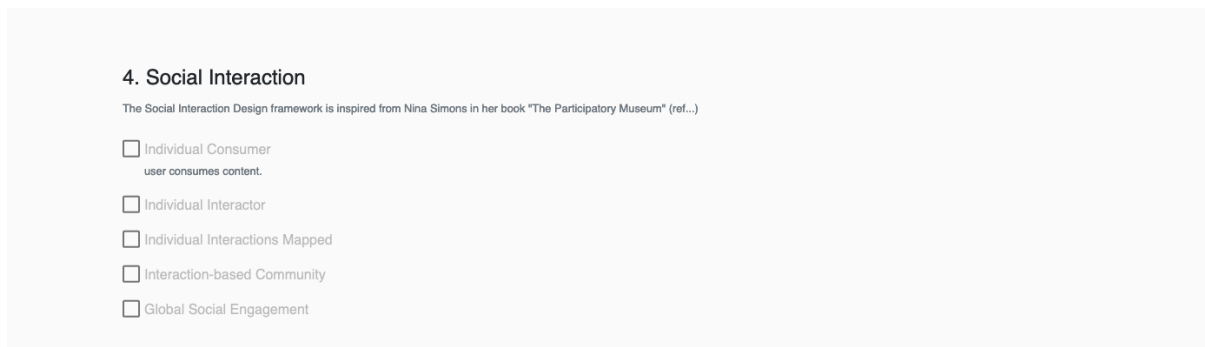
		Input	Output
	Visual Apparatus provides visual information/interactions.	<input type="checkbox"/>	<input type="checkbox"/>
	Audio	<input type="checkbox"/>	<input type="checkbox"/>
	Touch	<input type="checkbox"/>	<input type="checkbox"/>
	Spatial Orientation Vestibular sense of balance and spatial orientation	<input type="checkbox"/>	<input type="checkbox"/>
	Movement Proprioception or kinaesthesia: sense of self-movement and body position	<input type="checkbox"/>	<input type="checkbox"/>
	Gustatif	<input type="checkbox"/>	<input type="checkbox"/>
	Olfactif	<input type="checkbox"/>	<input type="checkbox"/>

Figure 8 - Input / Output Form

5.3.1.4 Social Interaction Scale

The fourth section of the form is related to the Social Interaction, as described in the section 5.2.3. It allows to select the social interaction stage an interactive apparatus would represent, namely:

1. **Individual Consumer** - in this particular case, there is no actual interactivity.
2. **Individual Interacts** - a one-to-one interaction between the apparatus and the interactor.
3. **Individual Interaction are Aggregated** - a one-to-one interaction, all interactions are aggregated to be shared with interactors and/or visitors.
4. **Individual Interaction are networked for Social Use** - a one-to-one interaction, all interactions are identified and shared.
5. **Individuals Engage with Each Other Socially** - a one-to-many interaction, interactors must work and collaborate together at some stage.



4. Social Interaction

The Social Interaction Design framework is inspired from Nina Simons in her book "The Participatory Museum" (ref...)

Individual Consumer
user consumes content.

Individual Interactor

Individual Interactions Mapped

Interaction-based Community

Global Social Engagement

Figure 9 - Social Interaction Level Form

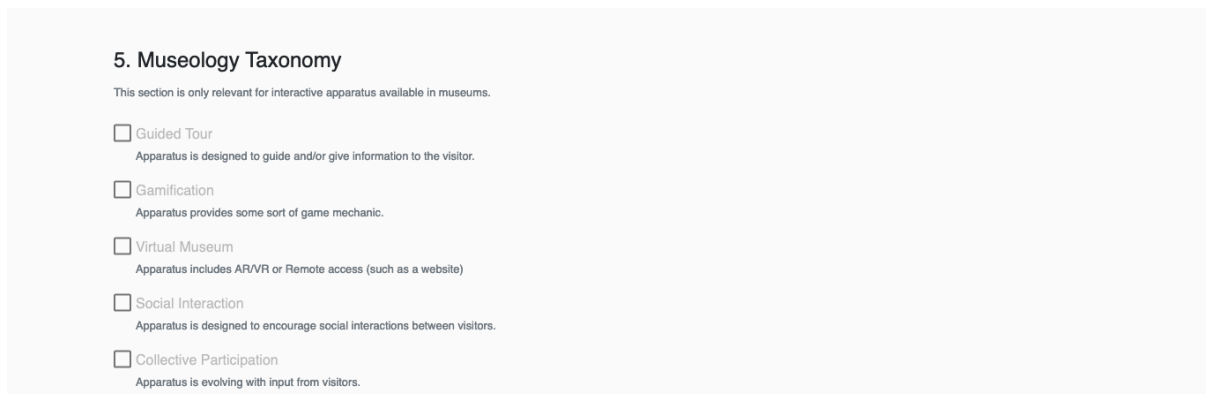
5.3.1.5 Museology Taxonomy

The final section of the form to add new interactive apparatus into the database described the museology taxonomy proposed in section 5.2.4. It includes:

- **Guided-Tour** - personalised guided-tour based on an interactive apparatus.

- **Gamification** - including entertainment.
- **Virtual Environment**
- **Social Interaction**
- **Participation**

These categories are not exclusive and therefore we choose a multiple-choice format for this taxonomy.



5. Museology Taxonomy
This section is only relevant for interactive apparatus available in museums.

- Guided Tour
Apparatus is designed to guide and/or give information to the visitor.
- Gamification
Apparatus provides some sort of game mechanic.
- Virtual Museum
Apparatus includes AR/VR or Remote access (such as a website)
- Social Interaction
Apparatus is designed to encourage social interactions between visitors.
- Collective Participation
Apparatus is evolving with input from visitors.

Figure 10 - Museology Taxonomy

Finally, we also have the possibility to edit and modify an existing interactive apparatus if needed. We are using the same form but pre-filled with the existing data.

Interactivity Analysis Framework
Search

Interactive Apparatus

Enter all the required information based on observation or interview with the author(s).

1. Apparatus

or Installation are interactive "dispositif" (or systems)...

Name
ENGauge

URL
<https://www.museumix.org/editions/2014/derby-2014/prototypes/engauge>

Place
Silk Mill Museum Museum

Type of event
Museumix Year
2014

City
Derby United Kingdom

Description
We're peoping a model railway with stories from the past, making a signal box a hands-on experience and enabling visitors to envisage a railway network of the future!

Technologies
Teensy 2.0 (like an arduino) Reed Switches (uses magnets) Python Audacity Arduino IDE Speaker Laptop iMac with Vine Aurasma A

Image link
https://www.museumix.org/wp-content/uploads/2014/11/lumbir_neo4nt9zrfl1u37rdao1_1280-768x564.jpg

License

Article
L'objectif We are TeamENGauge and we want to engage young people with the railway collections here at Derby Silk Mill.

2. Modes of Interactivity

MEDIUM

DIGITAL

AUGMENTATIVE

SOCIAL

PARTICIPATIVE

LEVELS OF COHERENCE

NONE - not interactive

RANDOM - level 1

RESPONSIVE - level 2

INTELLIGENT - level 3

3. I/O

Interactive Apparatus have some properties to understand or express to some human senses, they are the input and output of the apparatus to communicate.

	INPUT	OUTPUT
Visual Apparatus provides visual information/interactions.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Audio	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Touch	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Spatial Orientation Vestibular sense of balance and spatial orientation	<input type="checkbox"/>	<input type="checkbox"/>
Movement Proprioception or kinesthesia: sense of self-movement and body position	<input type="checkbox"/>	<input type="checkbox"/>
Gustatif	<input type="checkbox"/>	<input type="checkbox"/>
Olfactif	<input type="checkbox"/>	<input type="checkbox"/>

4. Social Interaction

Social Interaction Design framework is inspired from Nina Simons in her book "The Participatory Museum" (ref...)

Individual Consumer

Individual Interactor

Individual Interactions are Aggregated

Individual Interactions are Mapped

Social Engagement

5. Museology Taxonomy

This section is only relevant for interactive apparatus available in museums.

Guided Tour
Apparatus is designed to guide and/or give information to the visitor.

Gamification
Apparatus provides some sort of game mechanic.

Virtual Museum
Apparatus includes ARVR or Remote access (such as a website)

Social Interaction
Apparatus is designed to encourage social interactions between visitors.

Collective Participation
Apparatus is evolving with input from visitors.

SUBMIT

Figure 11 - editing form for an existing interactive apparatus

5.3.2 Data Visualisation

The web application allows us to view the list of all interactive apparatus already inserted in the database but give us as well the possibility to search and view details information about each interactive apparatus individually.

This is currently the only option available from the application and one of its current limitations that we hope to improve in the future.

The list of interactive apparatuses - figure 12 - gives an overview of each apparatus with some basic information such as:

- A photo,
- The name of the apparatus,
- The date,
- The name of the museum,
- The type of event (Museomix, exhibition...)
- Finally, it shows the modes of interactivity, including both the medium as well as the coherence.

The detail view of an interactive apparatus - figure 13 - is giving more information about both the general information as well as the full multivariate analysis framework evaluation.

Interactivity Analysis Framework

This analysis framework has been developed as part of an ongoing research related to interactive apparatus in museums and other public spaces.

Interactivity Hacking Museum Innovation











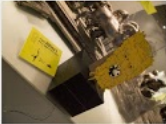






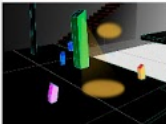



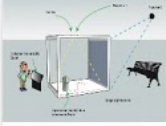


 <p>The Bold Furnace Coalbrookdale Museum of Iron 2013 Museomix</p> <p>augmentative</p>	 <p>Ironbridge Next Top Model Coalbrookdale Museum of Iron 2013 Museomix</p> <p>augmentative</p>	 <p>Iron Insight Coalbrookdale Museum of Iron 2013 Museomix</p> <p>digital participative</p>	 <p>It's in the bag Coalbrookdale Museum of Iron 2013 Museomix</p>	 <p>Superhero Visitors Coalbrookdale Museum of Iron 2013 Museomix</p> <p>augmentative digital</p>	 <p>The Pot That Changed The World Coalbrookdale Museum of Iron 2013 Museomix</p> <p>augmentative</p>
 <p>WOW Wonder of Water Coalbrookdale Museum of Iron 2013 Museomix</p> <p>augmentative</p>	 <p>Pimp my Room Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative participative</p>	 <p>Archi + Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative</p>	 <p>Enquête aux Arts Décoratifs Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative participative</p>	 <p>Et surtout... Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative</p>	 <p>#neverstop Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative participative</p>
 <p>icube Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative</p>	 <p>Palabrama Musée des Arts Décoratifs 2013 Museomix</p> <p>digital</p>	 <p>Verre le Rével Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative</p>	 <p>Nomades Musée des Arts Décoratifs 2013 Museomix</p> <p>augmentative participative</p>	 <p>ARTualité Musée de la Civilisation 2013 Museomix</p> <p>participative augmentative</p>	 <p>MUSÉES À IMAGES Musée de la Civilisation 2013 Museomix</p> <p>augmentative</p>
 <p>Il était 1000 fois.</p>	 <p>TAG</p>				

Figure 12 - list of interactive apparatus, partial view



Costumix

2014, Musée départemental Arles antique, Arles Museum Museomix

[LINK](#)

Venez découvrir et questionner les costumes d'Arles d'hier et de demain, de Cés/Arlésien à Star W'Arlésienne ! Prenez-vous en photos, puis créez votre costume à la manière d'un cadavre exquis . Et demandez-vous : suis-je mon costume ? Scénario utilisateur En exclusivité, le teaser de Costumix ! À l'aide d'une caméra, d'une console de commande tactile, d'un écran de projection et d'un panneau participatif, le visiteur est invité à questionner le rôle social du costume à Arles, depuis l'Antiquité et pour l'avenir. Le visiteur est invité à se positionner derrière la console de commande située derrière la statue d'Auguste, au centre du musée. Face à la webcam, il ajuste sa tête à la manière d'un photomathon et déclenche la prise photo quand il est bien positionné. Son visage est ensuite projeté dans le cadre entre les statues des danseuses, et vient compléter les éléments d'habillage présents à l'écran. Le visiteur peut choisir les habits qu'il souhaite porter : issus de l'Antiquité, des costumes traditionnels, ou reflétant le passé industriel de la ville. En glissant le doigt sur l'écran, il sélectionne son haut et son bas, et modifie son choix jusqu'à satisfaction. Le résultat peut être un costume 'complet', comme un habit complètement discordant ! Un costume complet enclenche la lecture d'un extrait audio. Un témoignage portant sur la signification du costume, sur son rôle comme marqueur identitaire individuel et au sein d'une communauté. Une fois satisfait du résultat, le visiteur écoute des extraits de témoignage portant sur la signification du costume à Arles, sur son rôle comme marqueur identitaire individuel et au sein d'une communauté. Il termine son expérience en contribuant à la réflexion « Comment imaginons-nous l'Arlésienne du futur ? » sur le panneau participatif. À la façon du cadavre exquis, il utilise les post-it et les feutres à sa disposition pour dessiner une tête, un torse ou un bas puis les intègre aux silhouettes déjà imaginées en piochant les composantes qu'il souhaite imaginer. Au fil de la journée, les Arlésiennes se multiplient, se font et se défont, au rythme de la fantaisie du visiteur. Voici les arlésiennes du futur les plus extravagantes imaginées par les visiteurs du musée :

Spectrum of Interactivity



Figure 13 - page showing the details information about an interactive apparatus

5.3.3 Data Analysis

Following the collection of data within the database, we can then use all this dataset into a statistical and graphical software such as RStudio¹⁹. RStudio is an open-source software massively used in academic research.

We have developed a simple R script - Appendix 2 - to analyse the dataset created through the web application. This script is allowing us to make some statistics on our current dataset, such as:

1. **Simple analytics** such as:

¹⁹ <https://www.rstudio.com/>

- Number of interactive apparatus per city and country,
2. **Distribution over our multivariate** - as value and graphics:
- Distribution of interactive apparatus based on the modes of interactivity,
 - Distribution of interactive apparatus based on the Social Interaction Scale,
 - Distribution of interactive apparatus based on the Input/Output grid analysis,
 - Distribution of interactive apparatus based on the Museology Taxonomy
3. **Maps:**
- Map of interactive apparatuses per country.

Details graphics and results are presented in the chapter 7 of our work.

Since our dataset is currently only composed of interactive apparatuses created within some of the Museomix events, the analysis of the type of event is not relevant for our work here but could be in the future if we can extend our database.

5.4 Conclusion

Museums have, all over the world, developed multiple strategies to engage their visitors and to provide a more interactive experience.

Whether in their physical spaces, in dedicated exhibitions or in a virtual environment, experimentations have all shown some limitations (Blöckner, Danti, & Forrai, 2009) and (Hornecker, 2008). Indeed, current technology or the complexity to apprehend it for the visitors are often a concern on a long-term approach. It is one thing to create a prototype and test it on a short period, it is something else to have a complete autonomous interactive apparatus integrated in the museum. One solution to this limitation could be by using more less

obstructive technology based on ubiquitous computer (Abowd & Mynatt, 2000). However, this type of technology is still in development or extremely expensive solution.

Still, most research with interactive apparatus inside museums, show an improvement in visitor experience, interaction with exhibits and their environment as well as enhance the visitor enjoyment and engagement. Despite those positive effects we can also note that it is sometimes not necessarily increasing visitor contextual knowledge (Zaharias, 2013): the original message defined by the curators around the exhibit and/or the historical and contextual value of the artwork itself might be lost to the visitor due to the interactivity itself or the layer added by the technology and/or the emotion it can generate. Psychology and visitor behaviour studies might be needed to improve those systems.

The table 2 shows the Multivariate Analysis Framework Table.

Table 2 - Multivariate Analysis Framework for Interactive Apparatus

Modes of Interactivity		Sensory Devices		Social Interaction	Museology
MEDIUM	COHERENCE	SENSING	INTERPRETING		
<i>Digital, Augmentative, Social/Participative</i>	<i>None, Random, Responsive, Intelligent</i>	<i>Sight, Hearing, Touch, Location, kinaesthetic, Taste, Smell</i>	<i>Sight, Hearing, Touch, Location, kinaesthetic, Taste, Smell</i>	<i>Consumer, Interactor, Aggregation, Participative, Social</i>	<i>Tour-Guide, Game/Entertainment, Virtual Environment, Social, Participative</i>

5.5 Future directions

The proposed framework in this chapter have been used in our study case as described in the chapter 6 and seems to cover all exploration in interactive apparatuses and technology in museums.

We have conceived this framework in an open way to allow extension and integration of future possible sub-sections. It is most probably only a starting point and we do hope that further research will help to enhance and refine it.

In the future, we plan to develop the web application in such a way that any visitors will be able to:

- View the list of already published interactive apparatuses,
- View the details of each interactive apparatus, as well as, whenever possible, have a link to the original website of the author(s).
- Search and filter through many criteria,
- Compare several interactive apparatuses,
- Comment, add photos and give feedback about a specific apparatus, for example if the person has visit and experiment it.
- Display statistics and graphics related to the current dataset, including - but not limited to: distribution per sub-section of the framework, maps aggregating number of interactive apparatuses per country, correlation between the variables.

Finally, provided that a person registers - free, he or she will be able to:

- Add new interactive apparatus,

- Discuss on a dedicated forum for development such as adding new variable of evaluation or any improvement to allow the application to be as useful as possible for research and analysis.
- Download the database for their own further analysis and publication.

We can also envision several extensions to follow up on this initial publication:

1. The first extension would be obviously extending this research to more interactive apparatus. We have currently one hundred apparatus analysed in the database, however we have one hundred twenty-five more apparatuses available from the Museomix database that could be integrated in the near future.
2. To further validate our framework, we would like to integrate interactive apparatuses that are not necessarily related to museum but any type of public spaces such as gallery, church, street or more. Looking at interactive technologies and media and the interactivity that it creates with interactor, it would be interesting to extend the research beyond museums to look at them in other contexts where people could be facing them. We could imagine studying some public spaces such as university campus or even library. Are interactive apparatuses generating the same behaviour and could we use the same framework in different environment?
3. The web application would be setup as a research database to collect, research and compare interactive apparatuses around the world. Using the proposed framework, we could find interesting patterns to research on.

CHAPTER VI

Experimental Study

6.1 Introduction

Following our discussion on Interactivity in Chapter 2, the Hacking methodology in Chapter 3 and finally, the proposed Framework in Chapter 5, we will, in this chapter, describe our experimental study.

We have studied several cases of interactive apparatus in museums in order to collect data and validate our hypotheses mentioned earlier.

Our experimental study is composed of two different study cases, namely:

1. Museomix, an international annual creative marathon within museums.
2. Two personal interactive apparatuses were developed in the course of this research within the context of museums and art galleries as well.

This chapter will look at a specific type of interactive apparatus that fit into our defined context as described in the previous chapters. The study case will focus on Museomix events and in particular, all their interactive apparatuses created during those events.

6.2 Methodology

Following our research question to propose a framework to classify interactive apparatuses based on their intrinsic properties, we have chosen to apply a qualitative research methodology. The quantitative methodology could have been followed if we were focusing our work on the interactor and the engagement with the interactive apparatus. In these cases, evaluating the interactor average time spent on each step of the interactivity could have been a research focus; this is possibly a future step following our current work: to measure the engagement and to be able to analyse it and compare it with on our multivariate analysis framework for interactive apparatus.

As we clarified earlier in chapter 5, our focus is the interactive property of an apparatus. We are not considering in this work the interactive experience of an interactor and his engagement. Although we are choosing a qualitative methodology for reasons mentioned above, this is not to say that quantitative methodologies are irrelevant per se, only that as our research question is of a qualitative kind, we have everything to gain by applying a qualitative research methodology.

As we have described our framework in chapter 5, we can now apply it to the data collected in the context of our work: in a museum and with a hacking methodology of a creative marathon.

Qualitative methodology as described by (Miles & Huberman, 1994) is required to be as objective as possible, and they proposed in their book a list of criteria to, as much as possible, validate the methodology. Although it is targeting at first natural science fields, we believe it can also be applied to our work since we are using a similar methodology; this creates the following list:

- Objectivity - Although we have indeed been involved in a few prototypes (1 as a team facilitator and seven by a discussion with the team members), the framework does not allow us to input our point of view since we are looking at the physical attributes of an interactive apparatus and their technical background. Therefore, we believe that the analysis applies the same to all apparatuses.
- Reliability - Following the technical description of each interactive apparatus, one should be able to classify each one with the Multivariate Analysis Framework for Interactive Apparatus and end up with the same result as we are presenting here. We can also note that one of the futures works we are describing in chapter 7 is to make sure researchers can collaborate, comment and fine-tune the framework itself as well as the analysis of the apparatuses.

- Transferability - As we have mentioned several times in our work, we have developed this analytical framework for interactive apparatuses as a classification mechanism in a specific context, but we believe the context could be enlarged outside of museums as well.
- Application - We hope to be able to create a better map of interactive apparatuses and help all environments with such apparatuses to better understand their systems in order to serve their public better.

None of these required elements, alone or in combination, guarantee that the results will be valid, but they are decisive factors to validate our analytical process.

Regarding Museomix prototypes, we have analysed all prototypes available on their public database from the first edition in 2011 to the fourth edition in 2014 for a total of one hundred and two prototypes. Over these prototypes, we have analysed one hundred and one with our Multivariate Analysis Framework for Interactive Apparatus as we will explain below.

Over the total of interactive apparatuses evaluate from Museomix, we can identify three different cases of the evaluation process:

- One interactive apparatus named “Mur[Murs]” was developed by participating in teamwork during the edition 2013 of Museomix in *Musée Dauphinois*, Grenoble, France.
- Eight interactive apparatuses were experimented and discussed with the team through informal interviews during the edition 2013 of Museomix in *Musée Dauphinois*, Grenoble, France.
- Two interactive apparatuses have experimented after the 2012 edition of Museomix in *Musée Gallo-Romain de Fourvière*, Lyon, France, namely, “Six Pieds Sous Terre” and “Scriptomix”.

- One hundred two interactive apparatuses, from 2011 to 2014 editions, were analysed based on the original documentation available on the official Museomix database.

On the one hundred and two interactive apparatuses analysed, only one hundred of them have been used with our framework. We can note the following:

- One prototype was not interactive since it was a regular card game and therefore not considered for our work,
- One prototype was not documented enough for us to be able to analyse it properly,
- Some of the prototypes are not available in the database, either because the team did not complete their documentation work or in some cases, none of the museum teams has published their prototypes, most probably due to technical limitations.

6.3 Museomix

In this section, we are discussing the source of the majority of our interactive apparatuses, namely Museomix²⁰.

6.3.1 Introduction

Today museums are shifting from pure art exhibits and knowledge to encompass a more personal experience for visitors. All museums are re-evaluating their exhibits and more importantly, how they stage and contextualize these exhibits as well as the museum itself (which can include the building, the history of the museum and more). Critical questions for most of them are always the same: how to remediate the visitor experience? How to increase audience engagement and participation? Also, how technology can help in achieving these goals? (Jewitt, 2012).

²⁰ <https://www.museomix.org/>

Interactive technology has been regularly used in museums to experiment with new ways of re-inventing the audience experience, such as (Ciolfi & Bannon, 2002) or (Meecham & Stylianou, 2012).

Interactive art has been one possible answer to modern museums. The art itself encompasses an interactive system to engage with the audience and very often react to some human reactions, whether movement, sound or more. It is a research field well studied with its taxonomy (Candy & Bilda, 2009) and much experimentation around the world. It is also in essence experimentations focusing interactivity within the context of the exhibit, and there is no relationship with other artworks around nor with the museum itself.

However, we also can look at technology integrated within the museum itself or adding an interactive experience to some exhibits of the museum, meaning that the interactive apparatuses are not part of specific interactive artwork. Most studies have separate those interactive systems from interactive art in a sense where they are part of a global vision for a museum and not explicitly attached to an artwork although they can have an impact on artworks as well. We also proposed a new taxonomy to classified interactive apparatuses in museums based on their creative intention: personalized tour-guide, gamification, virtual, social interaction and finally, participation.

Our experimental study is gathering the concept described in earlier chapters, including:

- Interactivity, defined in chapter 2: an intrinsic property of an interactive apparatus, whether it is triggered or not by an interactor.
- The museum, defined in chapter 4: a cultural institution which is displaying exhibits or intangibles for the education or enjoyment of the public.
- Hacking methodology, defined in chapter 3: a multi-disciplinary, collaborative creative process to generate ideas and prototypes.

- A Multivariate Analysis Framework for Interactive Apparatus, defined in chapter 5: a framework to classify interactive apparatuses based on their interactivity properties - not considering interactor engagement. Therefore, in our evaluation, we are interested in the interaction potential rather than the engagement.

The proposed framework is about understanding the modes of interactivity and how we can better understand it and compare the interactive apparatus.

The context of our work is mainly focusing on the hacking methodology within the museum, at least for the vast majority of our interactive apparatuses. However, as we will discuss in the following chapter, we believe, our framework can be adapted to different context as well and therefore enlarge the possibility of classification. During the time of our research, we had the opportunity to create two interactive apparatuses that we also included here in our framework to validate our future research. Indeed, these two interactive apparatuses are not fitting our proposed context totally, and we will discuss them in detail in section 6.4 and 6.5.

6.3.2 A Creative Marathon for Museum

Since 2011, the not-for-profit international organisation “Museomix” has proposed an annual 3-days creative marathon event in museums around the world. As of now, including the 2018 edition, it is sixty-six museums and cultural places that have been remixed in twelve different countries.

The event is always happening in November, usually a weekend around the 8th to the 10th of the month. It is a global event; therefore, all museums enrolled in the current edition are “mixed” at the same time - not counting, of course, the possible time zone difference.

The ultimate objective of such an event is to bring new perspectives on typical problems faced by museums through a disruptive and creative process. It is trying to look at those problems with a different approach in all aspects: professional expertise, cultural as well as routines.

The approach and processes have been refined by the organisation over time in order to maximize the impact for museums, but the objective of the process remains the same.

As we described earlier, such event is using a multi-disciplinary creative collaboration: a collaborative work between different fields of expertise to open conditions for the emergence of new ideas and projects, in a kind of agile methodology (Maruping, Venkatesh, & Agarwal, 2009) applied to human creation.



Figure 14 - Team creation based on a first brainstorming. © Museomix, 2012

An important and strong choice of the early Museomix was to organise these events, creating prototypes and releasing all documentation, source code or assets under a Creative Commons license. It is important since it would allow the museum, or anyone, to base on one of the projects to create a permanent interactive apparatus in a specific museum or to create a commercial product, here are two examples:

- A Permanent Experience: “La Machine à contes” prototype created in the 2013 Museomix edition in the *Musée Dauphinois*, Grenoble, has been developed by the museum as a permanent interactive apparatus.
- A Commercial Product: the Museotouch - an open-source application developed by Erasme, a public entity and one of the founder partners of Museomix - has been commercialised by Biinlab.

Here are the steps of this hacking methodology:

- Set expectations: after brainstorming on several thematic suggested by the museum, projects are proposed by participants. Any project has only the three days of the event to finalise their concept, user case and eventually a prototype for visitors to experiment
- Stimulate initial interaction: participants will enrol in a specific project. A project will start if only it can gather six participants with each different set of predefined skills.
- Provide sufficient adaptation time and reflection: each team will work on their use case and prototype, presenting to all participants, the museum and the Museomix organisation team in a daily global meeting - see figure 15 - to get feedback from outside the team.
- Create situations to experiment: on the last afternoon, all prototypes are finally exposed in-situ, and the public is invited to come and experiment the prototype. Observations

from the organisation team and the museum can allow quickly to discuss and decide which prototype the museum which to keep for longer experimentation.



Figure 15 - Museomix 2013, *Musée Dauphinois*, Grenoble

The three days' event is ending after the first in-situ experimentation with the public. Following these steps, the museum can work with the organisation in order to continue the experimentation with some prototypes and in the longer term to decide to transform the prototype into a final integrated system within the museum.

The objectives are not necessarily to create interactive apparatuses nor to use the latest technology, although the expertise is available. After four editions of Museomix - 2011 to 2014 -included in our database for our work, we must recognise that only one prototype cannot be considered as interactive - as we defined it in chapter 2: a computer-based system that includes

sensory representations. Technology is used as a powerful tool to make a reality the concept developed by a team. The technology is not used because of its hype or its novelty, but it is rather used for a very practical need to develop a project. It is interesting indeed to note that within a traversal view of a multi expertise team and due to the time constraint, technology is viewed as the best solution to achieve in a short time a specific goal like a prototype.



Figure 16 - “Lugdunum révèle-toi” prototype. © Museomix, 2012. Augmenting a 3D map.

We have participated in this event in 2013 as part of a team in the *Musée Dauphinois*, Grenoble, France. This experience was the beginning of our experimental work as we could participate in a Museomix project as well as discuss with all the other seven teams working during this edition in Grenoble.

We have since then participated in other similar events in different contexts, not a museum anymore but a church as well as a university. They all have the same concept of a few days' events with a hacking approach.

6.3.3 Stakeholders

An event such as Museomix is made in order to help to disrupt or at least suggest new experience to our traditional approach of a museum. In the case of Museomix, it is not a solution provider for museums in need of innovation, but it is a laboratory to create a new dynamic among people and experiment with some ideas quickly. However, we cannot yet state on the long-term impact of these new practices like Museomix. It is possible that they can help to transform the future of museums, but we will need to continue to observe and study them in the coming years.

For our discussions with the organisation team, some of the museum management team and some of the participants, they all recognise that Museomix is having an impact on all the stakeholders of the museum, namely: the museum itself, the museum professionals, participants of the event and finally the visitors.



Figure 17 - “Storytelling” prototype. © Museomix, 2012. Unveiling a Roman epitaph

6.3.3.1 Museum

The methodology proposed by Museomix and described earlier has been applied to different category of museums: art and fine art museums, natural history museums, antique and history museums, science museums as well as industry museums.

Museums applying to organize in their facilities such event are also put to a very dense experience at all levels: infrastructure, organisational, human resources but also artwork resources, space, time and security. Not only they must show their motivation and commitment, but they are also required to agree to the Museomix Charter.

Not all prototypes resulting from the experience are kept longer for public experimentation or fully developed into a complete integration within the museum. The final decision remains on the museum management: some are integrated, but other are removed due to technical problems or sometimes simply because they are too disruptive in their perspective or because they do not fit in the museum philosophy.

An example of prototype not developed by a museum is the one represented in Figure 18: a space in the middle of an old church part of the museum where the team set up sofas to encourage visitors to lay down and feel comfortable to watch the richly decorated rooftop of the church. The setting was complemented with a tablet to control the audio guide and a synchronise lighting system to highlight the specific part of the church discussed. The experience was acclaimed by all stakeholders as a simple but very creative way to encourage visitors to look up and learn the old code of the sixteen-century Christian artists. However, the prototype was finally not kept and developed, not for technical reasons but rather because the museum was not yet ready for such an experience for their visitors.



Figure 18 - Museomix 2013, prototype “Lever les yeux”, Grenoble, France

6.3.3.2 Museum staff

One of the required conditions for any museum to enrol to a Museomix edition is to make sure of the motivation and enrolment of their professional staff throughout the event. Obviously, these people will be involved at different levels of the event, but it is important for them to live the experience from inside as well as to make sure the event can run smoothly with the maximum support from the museum.

Professionals from the museum are also included in some teams based on their skills (usually as a content expert). Since one of the objectives is to engage museum people out of their routines and in the remediation of their own museum, it is important for them to be immersed in the experimentation and not to be only spectators. This is usually a disruptive experience for them, but most of them are clearly saying afterwards that it is also an open-eyes experience. They are then looking at the museum with a totally different perspective, a perspective that is

not present in their traditional professional's patterns and hopefully, will have an impact on their future work.

6.3.3.3 Participants

“Mixers” - the name of participants during the event - are by nature people motivated for a new and unexpected experience since they are registering and coming voluntarily. They are all joining this experience to be creative, to start new social connections and obviously to have fun as well since enjoyment can be seen as one of the conditions for creativity as mentioned in chapter 3.

People can apply to become a “mixer” by freely registering and specifying their expertise area. Close to the event date, the organisation team will select the final participants to make sure they can cover all fields of expertise required. At that time, participants will have to commit, and they will also have to agree and sign the mixer charter.

To create a multi-disciplinary team, the organisation has defined six profiles with the following skills:

- COMMUNICATION - document the concept and keep the prototype alive on social networks.
- CONTENT EXPERTISE - a source of scientific knowledge, usually someone from the museum.
- MEDIATION - the face of the project for the public, transmit the concept and its storytelling.
- GRAPHIC DESIGN - give a form and a branding to the concept. Could be a designer or an artist usually.
- DEVELOPMENT - identify the technical solution and make sure the interactivity of the prototype is working.

- FABRICATION - make the body of the prototype through any traditional technique or digital fabrication. Wood and cardboard are used a lot for these types of work.

Each team will work on a chosen project to remediate a specific aspect of the museum. Mixing skills or multidisciplinary, is an excellent way to try to auto-generate lateral thinking, as described by de Bono (Edward De Bono, 1970).

Teams are required to document every aspect of their project: user case, goals, tools and technologies used - including any source code produced - and some lessons learned or recommendations for the future of the prototype. This requirement is to facilitate any future development as well as research.

Finally, each team has one extra member: a “facilitator”. This member is the link between the team and the organisation team.



Figure 19 - Multidisciplinary team working at Museomix 2013, France

6.3.3.4 Visitors

As museums will have no meaning without visitors, it is important to study visitors reactions and interactions with those new interactive prototypes. This is only with an in-situ experience that the museum is capable of determining whether the prototype is worth going further.

The last afternoon of the event, the museum is re-open to the public, and they are invited to take a visit to the museum and encourage to test and manipulate each prototype as well as discuss with the team in charge.

At the end of the event, the museum can decide to keep some prototypes to test them longer in order to have a better observation of the audience interactivity and its level of enjoyment.



Figure 20 - "Arrête ton char Benhur" prototype. © Museomix, 2012. A Roman chariot race

6.3.4 Conclusion

Museums have developed different strategies to provide more interactivity and audience engagement in their facilities and exhibitions. The multidisciplinary creative collaboration approach proposed here could be seen as well as a new interactive process that museums could use as a more global approach to remediate part of their spaces.

This multidisciplinary creative methodology proposed is interesting in several aspects:

- It is focusing at first on collaborative human creativity to bring disruptive thinking and therefore allowing a potentially higher level of creativity.
- The user case is the driver for the interactivity and the technology.
- The technology is mainly used to integrate and highlight the museum itself or a specific part - exhibit, room and more.

It is also important to describe the limitations we can already identify from our experimentation:

- A 3-days event cannot allow developing extremely advanced installation prototypes, and it is sometimes difficult to give a real user experience with a very preliminary prototype.
- Between an interesting prototype and a final system fully integrated within the museum, the cost and the time of implementation can be both very high and not necessarily economically viable for a museum.
- Managing 100 people during three extremely dense days can be sometimes difficult, and human tension can always happen and need to be managed properly.

Similar approaches have also been seen recently in a lot of other organisations or events that could be as well research to further study and understand. Barcamps, Hackerspaces or Fab Labs could be some potential candidates to continue this research in a more transversal study.

6.4 Yan Character

This section introduces the first of our personal exhibition related to interactive apparatus: the live exhibition of the Chinese “Yan” Character.

6.4.1 Introduction

This experimentation has taken place in the art gallery Creative Macau at the end of 2016, and an academic presentation at the Artech conference as well as a publication (Estadieu, De Abreu, & Barbosa, 2017) followed in 2017 with the Association for Computing Machinery.

Although this experimentation took place in a different type of environment - an art gallery instead of a museum - and with a different creative approach - traditional design thinking instead of hacking approach as described in chapter 3 -, we include this particular experimentation in our work. Indeed, our installation includes an interactive apparatus, and we wanted to validate our framework outside the scope of our main context - an interactive apparatus in a museum and created with a hacking approach.

We propose to describe and analyse the participative installation art “Standing Humanity: 3D Yan Character”. In the perspective of our current work, we want to evaluate if we can use an interactive apparatus with our multivariate analysis framework within a different context - not in a museum and not based on hacking approach.

6.4.2 Contextualisation

For the last 40 years, since its creation, the additive manufacturing industry has improved technologies, lower costs and continuously reached a new limit in quality for the physical representation of 3d computational models. However, these technologies have remained expensive and hard to access for artists and researchers.

The end of some fundamental patents in 2009, has opened doors for a competitive market in the last decade. We have seen a lot of technological innovation, prices have also dropped exponentially and, as importantly, some very active and innovative open-source projects such as the RepRap (Jones et al., 2011) projects have emerged and have started to gain popularity, even in the younger generation and school environment (Eisenberg, 2013) and (Kostakis, Niaros, & Giotitsas, 2014).

3D printing technologies are nowadays more and more used for artistic installation around the world, providing a unique technology to create complex physical objects otherwise almost impossible to realize or at least extremely difficult.

It is a new source of inspiration for artists, allowing them to materialize their ideas and embody their concepts in new creative ways, new materials and shapes. An example of such creation can be seen in the installation “Next Industrial Revolution” by artist Gilles Azzaro or the project from Xuedi Chen and Pedro Oliveira “X.Pose”.

It is also opening new experimentation in exploring research and educational concepts by physically representing them in tangible objects, such as mathematician (Segerman, 2016).

From December 15th to December 30th of 2016 - see figure 21, we set up a participative installation art where we 3D printed an over two-meter-high Chinese character ‘人’. The public was invited, over the exhibition period, to see the full process of construction including the printing, assembling and glueing. Participants were as well encouraged in social interactions with the artists and participate in several areas of the installation.

The Chinese character “人” (pronounced “Rén” in Mandarin, “Yan” in Cantonese) was chosen for the following reasons:

1. its meaning in English is “people” or “human being”,

2. the shape of this character (the same in Mandarin and Cantonese) looks like a person standing and walking forward,
3. technically, the character is a simple shape compared to other characters, and it can easily be identified and remembered for the non-Chinese public,
4. the shape will allow the built character to stand on its own, without the need of any extraneous support.

The exhibition manifesto we developed in a short booklet available to the public was the following: “Technologies have a tremendous impact in our daily life, they have become fashionable, desirable and somehow they define us, they shape us, and they are giving us a social status. They are transforming our bodies and our lives to make us better humans or simply to keep us from our own evil side. But, as everything humankind is creating, technologies are also an extension of ourselves, a projection of our thoughts and feelings. A deep outreach to our social peers, a need from our souls to engage in relationships. To reach the sky. To touch the infinite.”



Figure 21 - Poster for the exhibition “Yan Character”

The Chinese character symbolically represents humanity and each block composing it represents individual and unique human beings.

The installation started without the Chinese character, which was printed over the course of seven open days, from December 15th to December 28th - due to numerous local public holidays in this period of the year. We included as well other participative 3d printed system to encourage and stimulate public participation as described in the next sections.

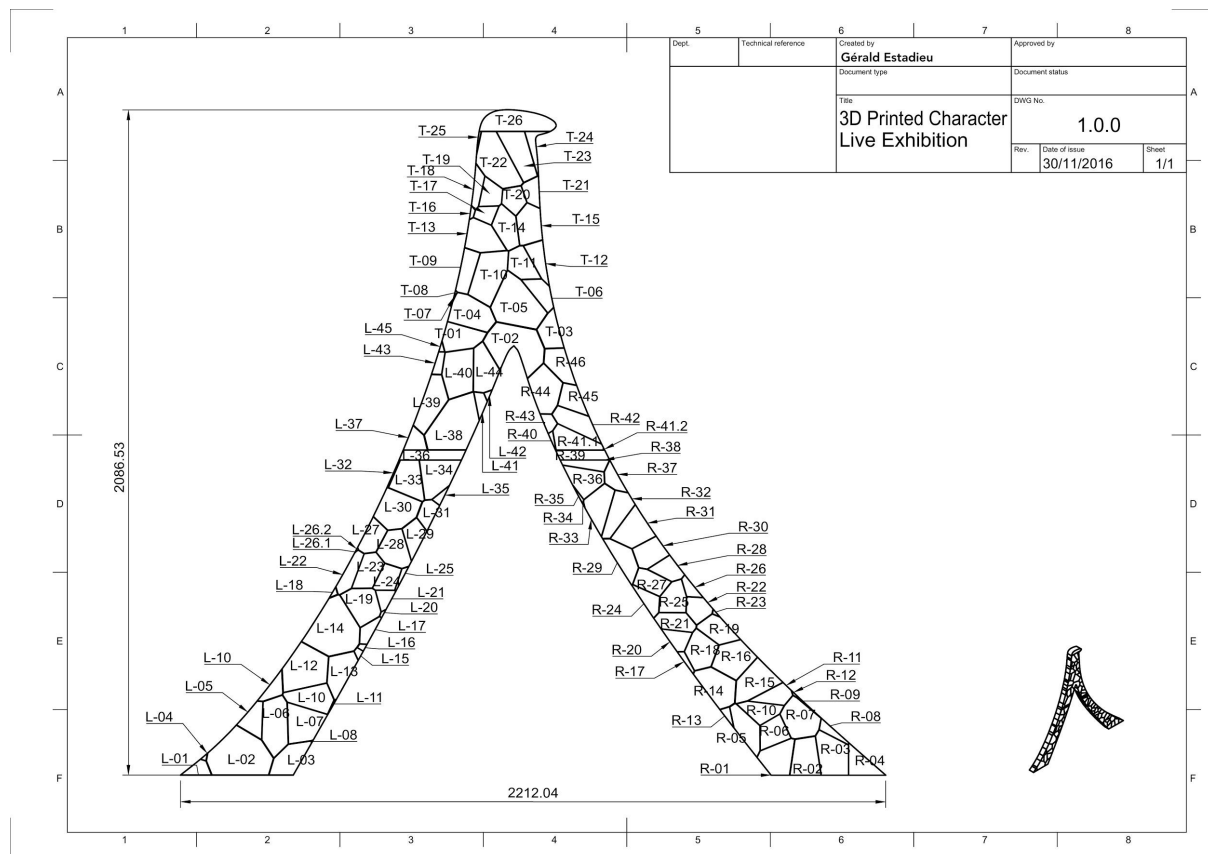


Figure 22 - Technical drawing for the full-size Yan character

6.4.3 Exhibition Space

This installation art was created for the Creative Macau – Centre for Creative Industries space where they offered us a reserved area to propose a new genre of 3D printing experience based on the original concept described earlier.

We designed the setting of the allocated space with several dedicated areas discussed below, as well as a large area on the middle created to invite participants to interact, play and participate as shown in figure 23 below.

A visual installation was created to integrate five printers in the overall installation. The printers were visible from the street to encourage people to stop, watch them and eventually enter in the exhibition space.

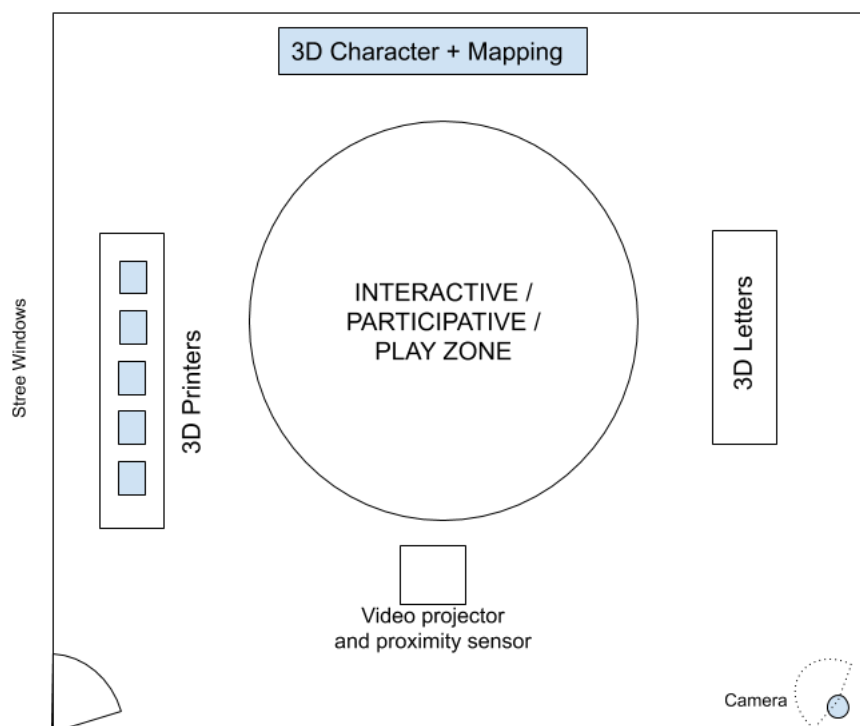


Figure 23 - The installation setting including four main areas: 3D printers, 3D letters, Character exhibition and finally the play area for the participants

Over the course of the exhibition period, participants could see all steps of the creation of the Chinese character as well as participate in activities related to 3D printing technologies. Due

to the live nature of the exhibition, participants will always have a different version of the installation art at a T time. For example, the signing of blocks could not be done on the very first day since no blocks were yet printed.



Figure 24 - night view of the exhibition with 3D printers printing and assembling in process

The preparation before the installation art started, included the following:

- The design of the allocated space,
- the 3D modelling of the Character and computer-generated pattern to create individual blocks,
- finally, the fine-tuning and experiment of the 3D printing software settings. The preparation time pre-exhibition took a month to define the best settings, sourced all materials and equipment and design the space organisation.

6.4.4 Design

The design of the Chinese character is based on a standard Chinese font character which has been slightly modified to have a flat bottom. Following the 2D drawing, the 3d model was designed with a 3D extrusion function. In order to not generate a simple cube, we choose to cut the model with a Voronoi diagram generated pattern applied to it. This type of pattern allowed us to generate unique, distinct and controlled-size geometrical shapes through a set of predefined input parameters. It then allowed us to obtain geometrical shapes that could fit in 3D printers used for this installation. Based on this pattern, we generated a total of one hundred and twenty blocks, all with different shapes from each other.

6.4.5 3D Printing

3D printing, like all digital fabrication technologies such as laser cutting or CNC milling, is comprised of 2 distinct and complementary parts: the first is software-based, and the second part is mechanical-based.

Following the design work described earlier, we generated one hundred and twenty 3D files in STL file, each one with a distinctive Voronoi-based shape. Once all blocks were exported from Autodesk Fusion 360, we used Simplify3D, a proprietary 3d printing slicer software, to prepare specific machine code based on a set of predefined rules and generate the final G-code file for each block. Each generated file was then sent to the queueing system of each 3D printers to be ready to be printed and create a physical representation of the computer-generated model.

Regarding the 3D printers used in this installation, the objective of this project was to be able to use consumer-grade 3D printers, all of them within an open-source and open-hardware license and in a price range lower than 3,000USD. These printers are all using the same 3D printing technology “Fused Deposition Modelling” which is the most common 3D printing

method and the most affordable currently, using a thermoplastic filament to create a physical representation of a 3D model.

All printers were remote-controlled on the local network using an open-source application: Octoprint running on a Raspberry Pi version 2 attached to each machine. This software allows us to plan the printing process as well as record statistical information and finally notify the artist once a machine completed a job or failure happened.

Each block constituting the Chinese character was printed in white colour with Polylactic acid filament, also known and commonly referenced as PLA, a biodegradable thermoplastic polyester. This thermoplastic is commonly used in the 3D printing industry for its ease of use as well as its low pricing. The white colour was chosen in order to use the final two-meter-high standing character as a screen for a generated spatial augmented reality projection.

6.4.6 Assembling

All the one hundred and twenty blocks were glued together based on the technical drawing generated from the original 3D model of the character. The glue used was a 2-parts epoxy glue and the standard curing time was about 24 hours. It was important to find a glue with a high strength bond coefficient but also a high viscosity to allow the glue to fill some of the gaps due to the imperfection of the 3D printing.



Figure 25 - blocks 3D printed with their reference code and positioned before glueing



Figure 26 - blocks 3D printed and signed by visitors

6.4.7 Interactive Spatial Augmented Reality

Since the Chinese character was printed in white colour, it was then used as a projection screen for a spatial augmented reality (Bimber & Raskar, 2005) projection, also known as projection mapping or video mapping.

A generative video animation with sound was created before the exhibition to highlight the following aspects of the Chinese character:

- size: since the final object was a tall sculpture of two-meter-high, the animation had to be at real scale;
- area: at the beginning, the area was empty, and it was important to keep the space alive, at least digitally.

The projection was triggered by a proximity sensor when a visitor will enter the interactive zone - see figure 27. We actually displayed the projection mapping since the first day on the spot where the character will raise two weeks later, and it helps visitors to understand what was happening and to measure the progress and completion of the installation.



Figure 27 - Spatial augmented reality triggered by the position of the visitor

6.4.8 Participation and Play

It was important for us in this exhibition to allow interaction between participants and the installation.

We designed two levels of interaction for the visitors to encourage them to become active participants:

- PARTICIPATION by signing a 3D block,

- PLAY with the 3D letters



Figure 28 - The installation art in progress

6.4.8.1 Block Signing

Participants were invited (through a bi-lingual poster or verbally by the staff) to sign with a personal message at the back of a 3D printed block before we glue it to the main Chinese character. This interaction was designed to be a long-term interaction and was a strong action for the participant in the sense that it is a permanent change to the Chinese character, their message and signature will stay on the 3D printed block long after the temporary exhibition finished. In other words, one person bounds to a block to make each block related to a unique human being.

6.4.8.2 Play with Letters

During the pre-exhibition period, we 3D printed 40 colourful capital letters from the western alphabet, including some double for the most popular letters (such as “E”, “A”, “S”...). Participants were invited to touch and play with the big colourful letters in their very own creative ways; essentially to make a word to send a message or simply their personal initials, their name and more.

This part of the installation was designed to give a temporary playful environment for both children and adults as well as a representation of the bi-cultural environment of Macau: between Easts (Chinese character) and West (Alphabet letters). To the contrary of the direct interaction mentioned in the previous paragraph, this interaction allowed temporary and very short-term participation that could be erased at any time by the participant which lowers the personal engagement and commitment and make it more as a playful experience.

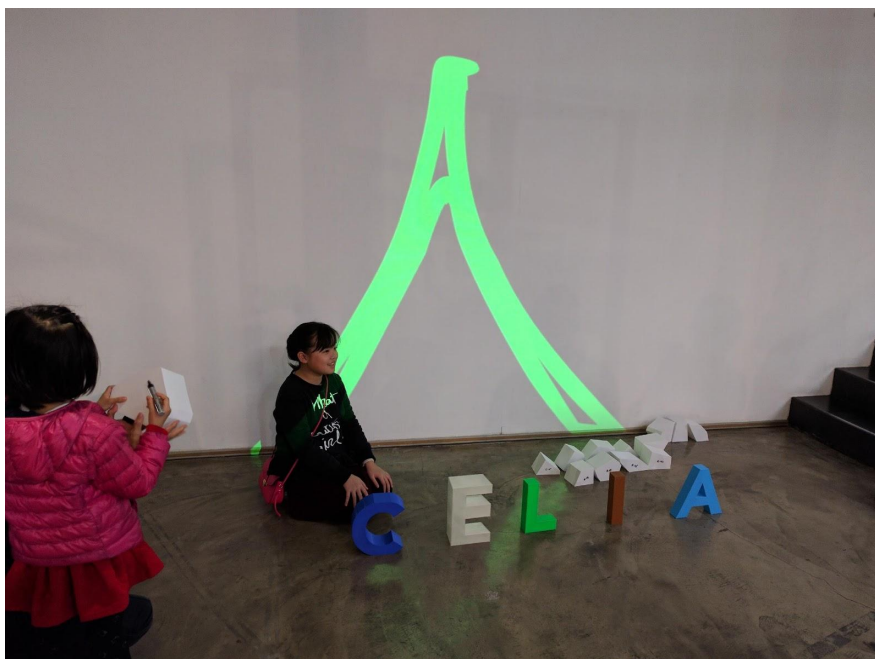


Figure 29 - The “Play with Letters” as well as the spatial augmented reality projection

6.4.9 Conclusion

This installation is integrated into our work to evaluate our multivariate analysis framework for interactive apparatus in a different context than Museomix. Indeed, with this installation, we are not in a museum, nor we have worked with a hacking approach. However, we believe our framework can also apply to this type of work.

This installation is considered as an interactive apparatus since we have a computer controlling the video mapping, and it is triggered by the interactor. Besides this interaction, we also have a participative interaction where visitors have signed a block with their own message; however, this part of the installation is not considered as interactive since the interaction does not enrol any computer-based system but simply a plastic block, a pen and a human inviting them to sign. We have, therefore, an installation where a part is actually participative but not interactive, which is preparing an interactive area since the signed blocks will then be part of the Chinese character with the video mapping. We can then conclude that our interactive apparatus is also participative due to its basic blocks.



Figure 30 - The final Chinese character standing

6.5 Italian Renaissance Drawings Exhibition

In this section, we present the second personal exhibition that includes an interactive apparatus.

6.5.1 Introduction

The exhibition “Italian Renaissance Drawings from the British Museum” took place at the Macau Museum of Art from April 11th, 2019 to June 30th, 2019. This exhibition presented for the first time in Asia, fifty-two drawings from a total of forty-two different Italian Artists from the Renaissance period, including drawings from some of the most famous artists such as Leonardo di ser Piero da Vinci, Michelangelo di Lodovico Buonarroti Simoni or Raffaello Sanzio da Urbino, known as Raphael.

We were invited to propose an experimental alleyway within the exhibition hall to develop tangible apparatuses representing some drawings. We have then selected sixteen original drawings representing the six different areas of the exhibition from the British Museum, namely: the Human Figure, the Movement, the Light, Costume and Drapery, the Natural World and finally the Storytelling.

We defined a few rules for our creative process as well as per discussion with the museum:

1. **TANGIBLE** - we wanted to transgress the traditional museum setting where visitors are forbidden to touch the artwork - for good reasons, of course - therefore, all exhibits we created where to be touched.
2. **ACCESSIBILITY** - one of the important requirements was to experiment how we could make the museum a little bit more inclusive and particularly toward visually impaired visitors, as shown in figure 31. This aspect was always one aspect of each of

our exhibits to try to find a new experience of the museum for a public that could before only listen to the guiding voice.

3. **LOCAL CREATION** - all exhibits would be produced in Macau with technologies that are currently available in our Digital Fabrication Laboratory of our Faculty of Creative Industries and the support of some of our students.



Figure 31 - the three busts of Da Vinci, Raphael and Michelangelo experimented by visually impaired visitors

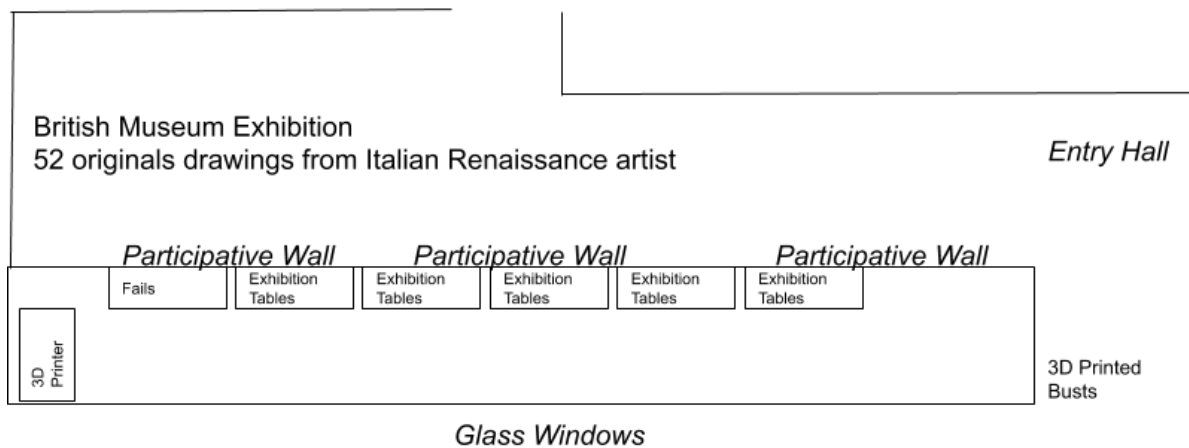


Figure 32 - Exhibition setting

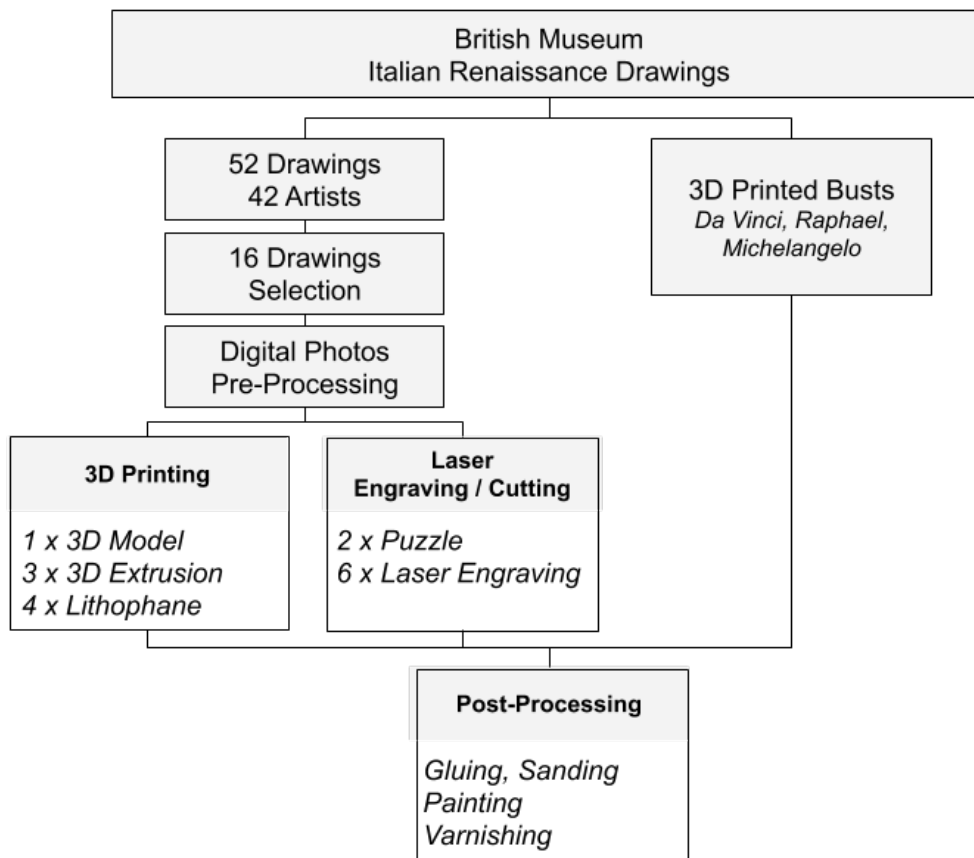


Figure 33 - Technical and Artistic Creative Process

Table 3 - List of drawings selected from the British Museum drawings

#	DRAWING TITLE	ARTIST
I - The Human Figure		
#19	A nude man seen from behind. See Figure 35	Luca Signorelli
#20	Caricatures - 2 faces	Leonardo da Vinci
#24	A nude woman sleeping	Rosso Fiorentino
II - Movement		
#30	A nude man attacking a snake See Figure 34	Circle/School of: Andrea Mantegna

#35	The punishment of the Avaricious: Study for Florence Cathedral See Figure 36	Federico Zuccaro
III - Light		
#37	Three head studies	Giovanni Bellini
#38	Design for hexagonal building with dome roof	Anonymous
IV - Costume and Drapery		
#46	A young man climbing stairs, seen from behind	Francesco del Cossa
#49	Three studies of a bishop	Vittore Carpaccio
#52	Studies after Paolo Romano and the antique	Girolamo da Carpi
V - The Natural World		
#57	Two youths resting in a landscape See Figure 37	Domenico Campagnola
#59	An ostrich See Figure 38	Giulio Romano
#61	Horses fighting	Taddeo Zuccaro
#62	The cultivation of silkworms	Taddeo Zuccaro
VI - Storytelling		
#67	St George and the Dragon	Giovanni Antonio Sodoma
#27	Hercules and the Centaur See Figure 39	Raphael

Figure 32 shows the setting of the exhibition, next to the exhibition of the original drawings and connected to the entry hall of the exhibition area.

Figure 33 shows the creative process to produce the sixteen tangible or interactive apparatuses. We used two types of technology: 3D printing and laser engraving/cutting. Both of them are then followed by traditional artwork - post-processing.



Figure 34 - #30, A nude man attacking a snake by Andrea Mantegna and our exhibit



Figure 35 - A nude man seen from behind by Luca Signorelli and our exhibit



Figure 36 - #35 The punishment of the Avaricious: Study for Florence Cathedral by Federico Zuccaro



Figure 37 - #57 Two youths resting in a landscape by Domenico Campagnola and the lamp



Figure 38 - An ostrich by Giulio Romano



Figure 39 - #27 Hercules and the Centaur by Raphael and the engraved version

6.5.2 An Interactive Apparatus

The majority of our exhibits cannot be considered as interactive apparatuses since they were not including any computer-based system and therefore will not be studied in our current work. However, we have selected one, the “Hexagonal Building Lithophane Lamp” - as shown in figure 40 - as part of our research work: indeed, this lamp was interactive since it includes a simple remote control to modify the lighting ambience and colour through a basic controller. We chose to integrate this exhibit in our database not only because it is interactive but also to validate the fact that our Multivariate Analysis Framework for Interactive Apparatus can also work on interactive artwork.

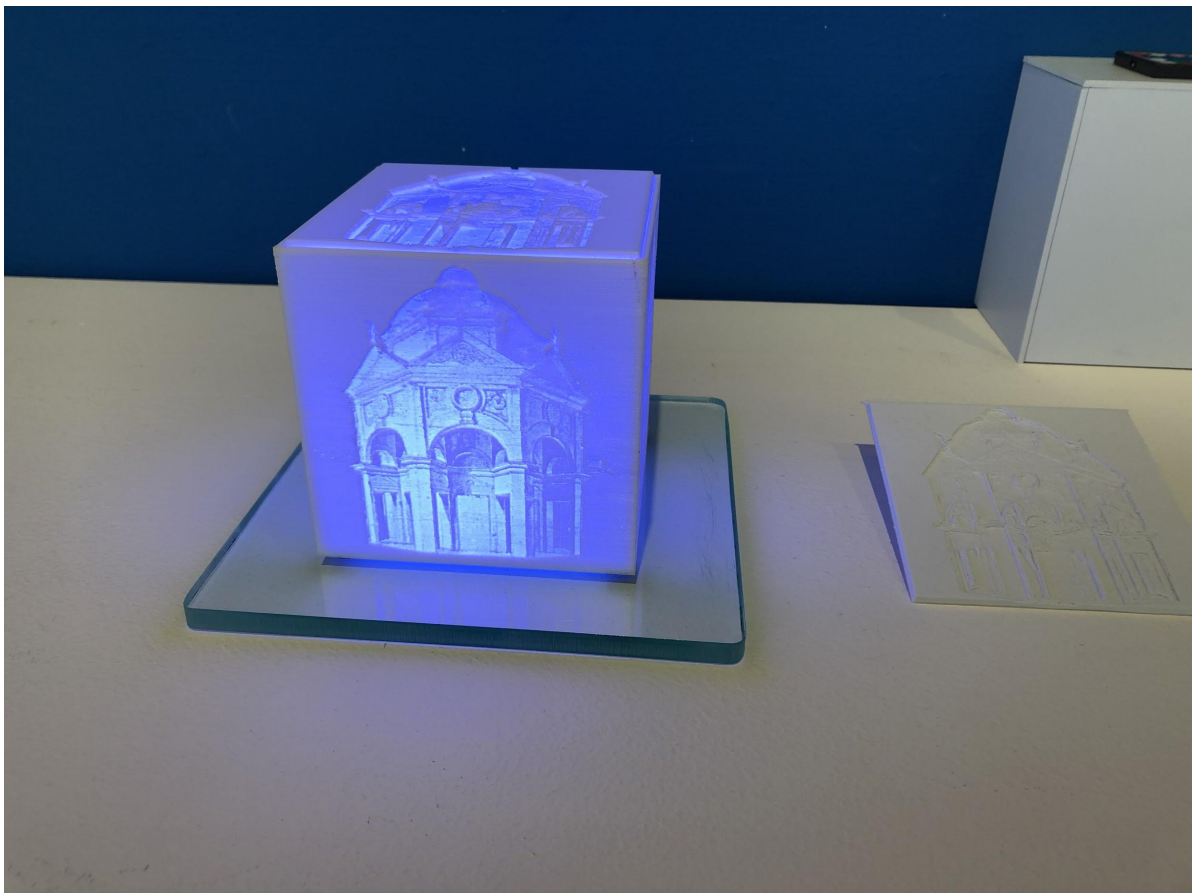


Figure 40 - interactive lithophane lamp with a drawing of a hexagonal building study (anonymous artist)

6.5.3 The Participative Wall

Besides the exhibits we presented during the exhibition, we also proposed a participative experience for the visitors - see figure 41. Indeed, visitors were invited to leave their mark on the wall of the exhibition by sharing their own drawings as a way to encourage visitors to share their feelings about the visit and its experience.

To celebrate these precious artists and their drawings, we also wanted to inspire visitors and let them express their creativity in a way that is not a natural expression in a museum setting. Again, it is a way to show how disruptive actions and hacking can be extremely inspiring for visitors.

Although the exhibition ran for almost three months, it only took a month to fill not only the area at the entrance of our section of the exhibition but visitors “naturally” extended their expressions over the all alleyway wall.

This has shown us that participative experiences can be a unique experience for visitors in a museum. Although this particular case is not an interactive apparatus as we defined it in chapter 2, we believe it is a good example to explain a participative experience within the context of a museum.



Figure 41 - example of drawings by visitors in the early days of the exhibition

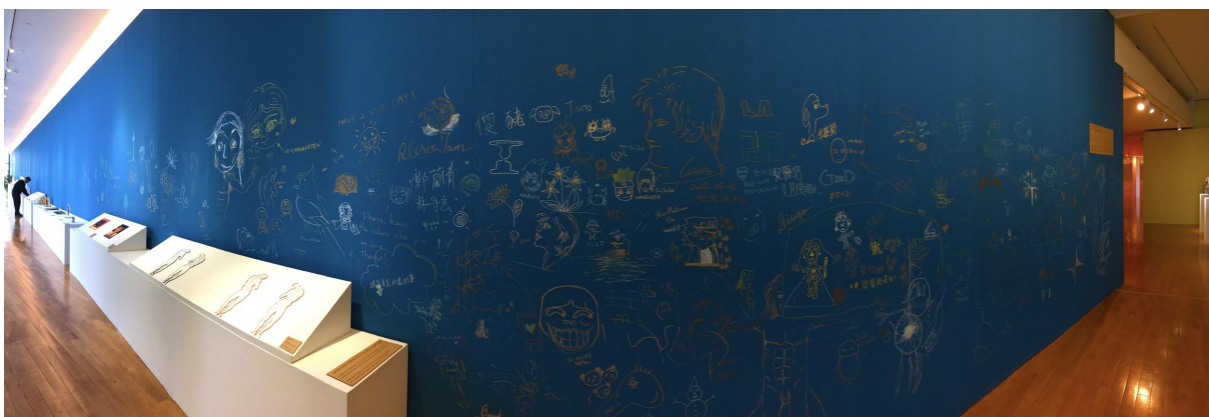


Figure 42 - The Participative Wall in the exhibition

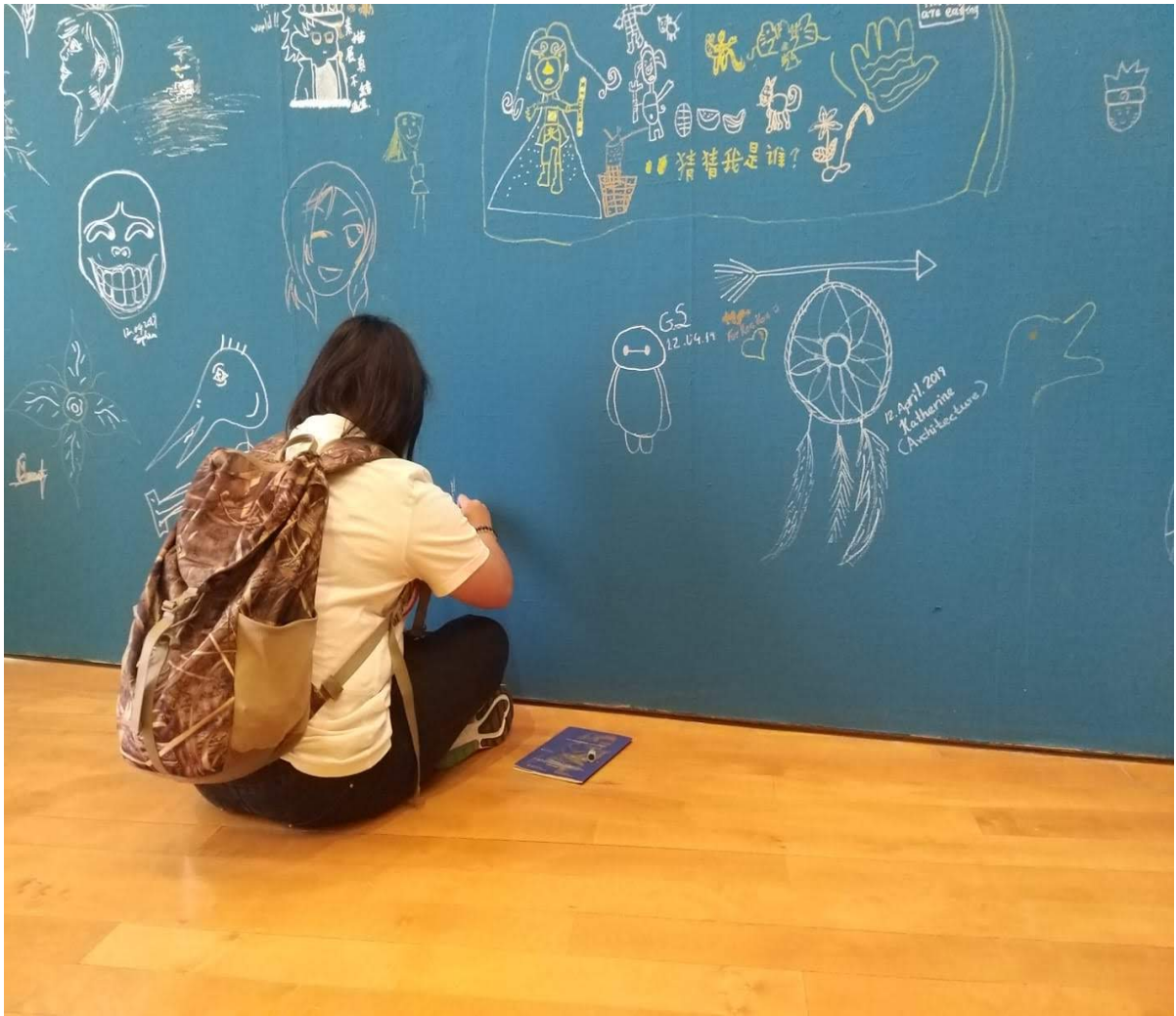


Figure 43 - a school student drawing on the participative wall

6.6 Conclusion

This chapter has described the context of our experimental study with three separate different settings:

1. Museomix: a hackathon-style -or creative marathon - event with the objective to propose innovative or disruptive experience of the museum as well as an experimental prototype for the public to test.
2. the "Yan" Character Live Exhibition is a live interactive and participative exhibition in an art gallery.
3. The Italian Renaissance Drawings is an exhibition in a museum with tangible exhibits, interactive apparatuses and a participative but not interactive experience for visitors.

Museomix is the core part of our work since not only it includes interactive apparatuses in a museum, it is also based on hacking methodology as we introduced in chapter 3 and we collected and studied one hundred of these interactive apparatuses in our framework.

Moreover, the experience in the Macau Creative Art Gallery allowed to conclude that our framework could be extended to interactive apparatus outside the strict context of this research; this is promising for our future work as we will describe it in chapter 8. Regarding the exhibition at the Macau Art Museum, it was also an important work to validate the idea of an interactive apparatus within a museum again - but not created with hacking methodology - can be considered by our framework.

CHAPTER VII

Data Analysis and Conclusions

7.1 Introduction

This chapter is, following the two previous chapters, namely:

- chapter 5 on the proposed framework to analyse interactive apparatuses and,
- chapter 6 describing our experimental data collection within the context of Museomix,

We will first describe the population participating in Museomix events to understand its demography better. We will then study in section 7.2 some descriptive statistics related to our dataset collected with our Multivariate Analysis Framework for Interactive Apparatus. Finally, we will conclude our work to understand how did we answered our research questions introduced in chapter 1. We will also identify what the constraints and limitations of such a framework and how we are planning our future work related to this initial research are.

7.2 Demographic Information

Before diving into the data collected during our research, it is essential to have a brief understanding of the demography of participants at a Museomix event. Although it is an event opened to a broad public, the expertise required is pre-selecting particular type of the population.

Since a local community organises each Museomix and although they have standard regulations and objectives, collecting data is often not the priority in a hectic weekend. Moreover, most reports are focusing on prototypes and audience engagement during the last day opening. Therefore, there is, most of the time, no complete official and global report from all Museomix events, unfortunately. However, for the 2014 Museomix edition, a global report has been produced and published, and we can extract from there some valuable information for our demography.

The 2014 Museomix edition was including the following museums:

- *Musée Départemental Arles Antique*, Arles, France

- *Silk Mill Museum*, Derby, United Kingdom
- *Musée d'Art et d'Histoire*, Genève, Switzerland
- *Musée d'Histoire Naturelle*, Lille, France
- *Musée des Beaux-Arts*, Montréal, Québec, Canada
- *Musée d'Histoire Naturelle*, Nantes, France
- *Musée d'Art et d'Industrie*, Saint-Etienne, France

However, we must note that the *Silk Mill Museum* did not submit any data to aggregate for this report.

A team of students interviewed a total of 391 participants for this report, out of more than five hundred participants - not all participants interviewed have answered all questions. Figure 44 shows the global ratio between female and male; we can see a higher number of female participants, about 64% of participants are female.

We have also looked at several partial reports from other Museomix editions, and we can always see the same tendency of a higher number of female than male, although not necessarily with such a high ratio of 64%. We can, therefore, conclude that females are, in general, more involved and interested by an event such as Museomix, at least as participants as those numbers are not including organisational, support or communication teams - only people working in the prototype teams.

Female / Male Ratio
2014 Museomix Participants

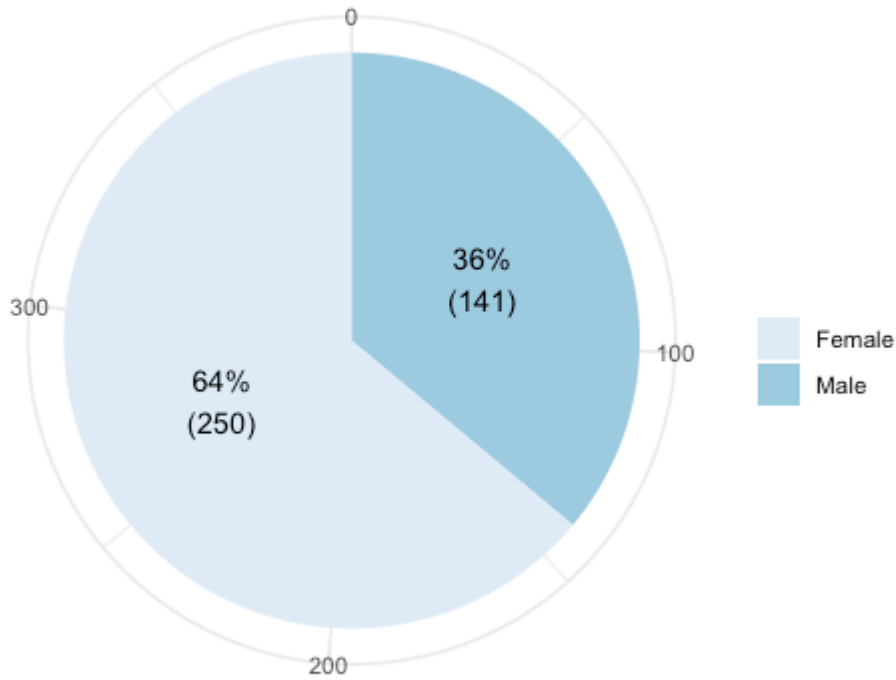


Figure 44 - Female / Male ratio, Museomix Participants 2014

Regarding the age of participants, we can also find some information from the 2014 Museomix edition global report. Based on these data, we have generated Figure 45 to represent the distribution of age groups. It is worth to note that:

- Almost 40% of participants are between 20 and 30 years old,
- More than the majority of participants - 73% - are less than 40 years old.

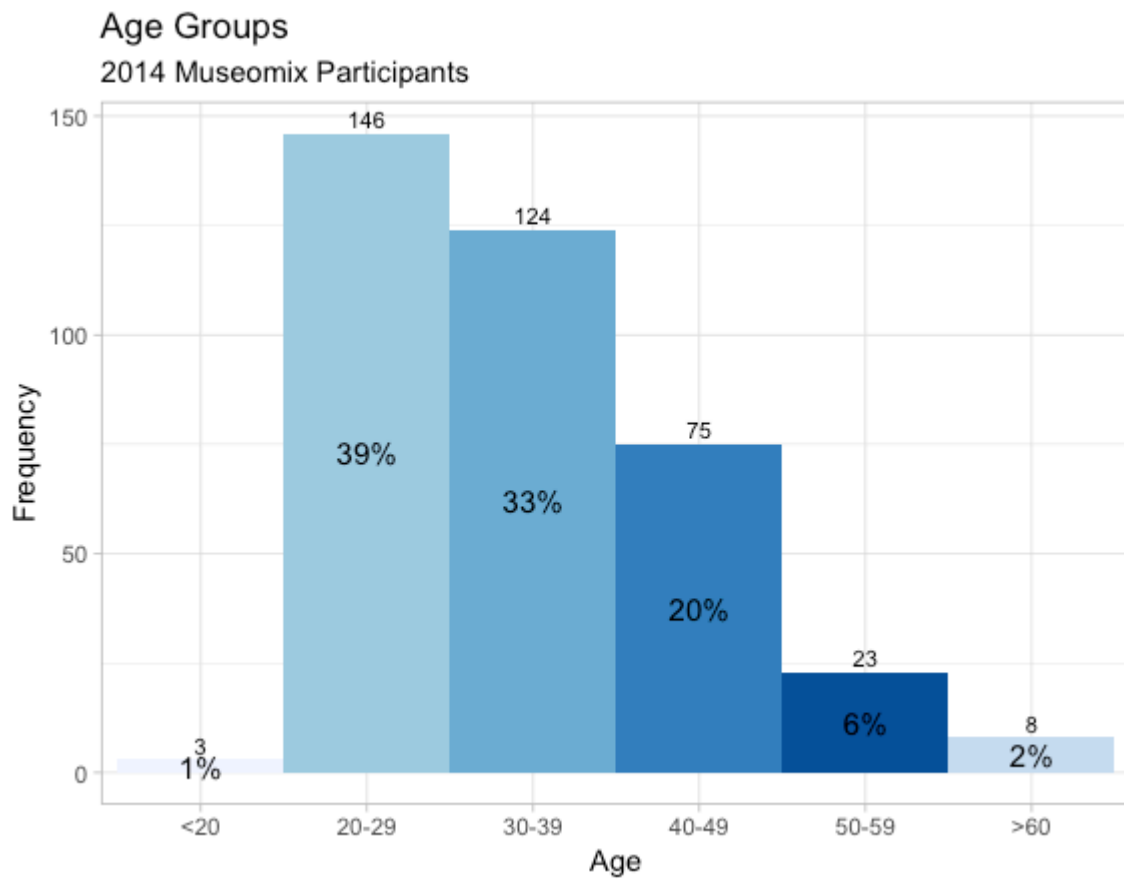


Figure 45 - Age Groups, 2014 Museomix Participants

Regarding the education level of participants, we can also find some valuable data in the 2014 Museomix edition global report. Figure 46 represents this dataset and clearly showing that the majority of participants - 67% - are Master holder and that 75% of them hold at least a Master. It appears that participants are highly educated.

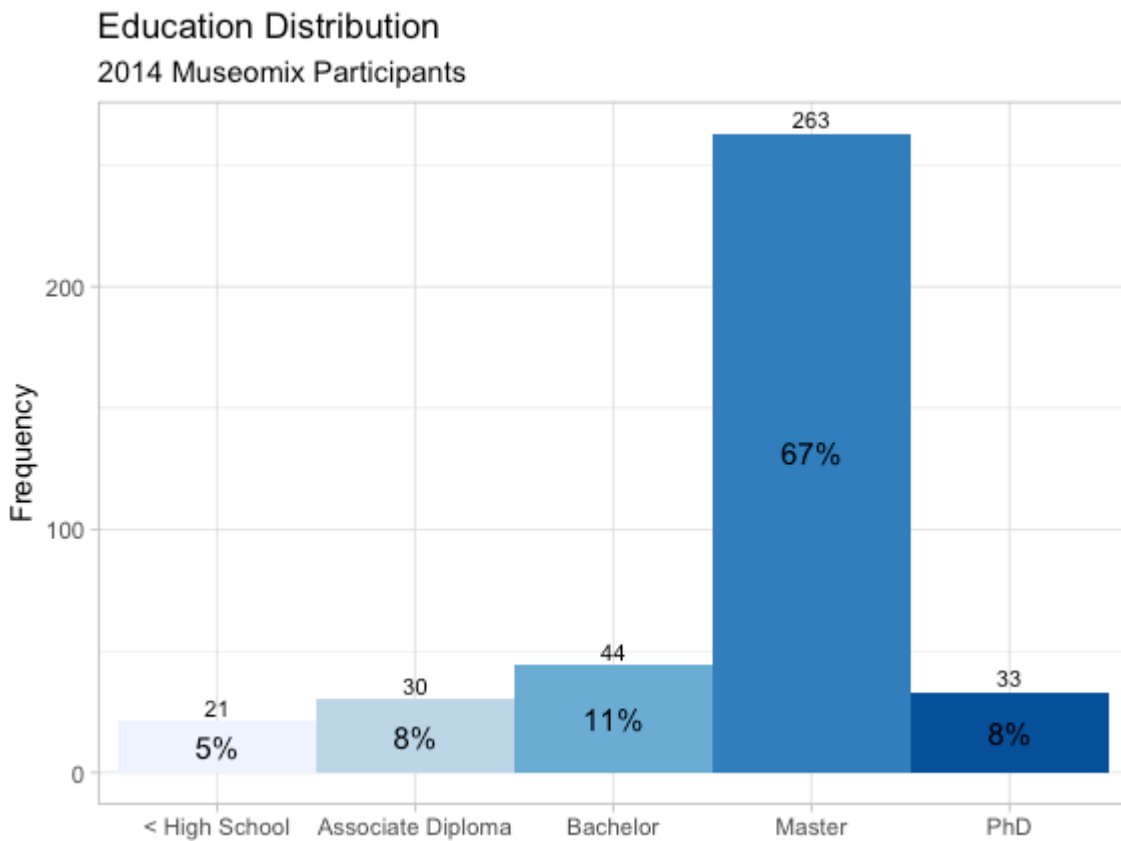


Figure 46 - Education level distribution, 2014 Museomix Participants

To conclude this preliminary study of participants, we can highlight the following:

- The majority of participants are female;
- Participants are mostly between 20 and 40 years old;
- Participants are highly educated (Master or PhD).

7.3 Understanding Interactivity

As we have discussed in chapter 5, the proposed framework to analyse and classify interactive apparatuses is composed of multiple variables, namely:

- Modes of Interactivity, including:
 - Medium: describing the interfaces of an apparatus,
 - Levels of Coherence: describing the mode of a dialogue of an apparatus,

- Sensory Representation, based on the representation of the human senses, including:
 - Sensing Devices: what type of sense-equivalent the apparatus is using to understand the interactor.
 - Interpreting Devices: what type of sense-equivalent the apparatus is using to communicate to the interactor.
- Social Interaction Stages: how social is the interaction with an interactive apparatus.
- Museum Taxonomy: a classification for the museum only - the context of our work - to represent the type of activities is proposed by an interactive apparatus.

7.3.1 Modes of Interactivity: Medium

We analysed all our interactive apparatuses to generate Table 4 to show the aggregated data for the medium used. An interactive apparatus can have several mediums, whether they are used in parallel or sequentially is not considered at this stage in the framework. Since it is a multiple-choice selection, this explains why we have a total number of 132 of mediums, although we only have 101 interactive apparatuses in our database.

Table 4 - Aggregated data for Medium of Interactivity

MEDIUM	FREQUENCY	PERCENTAGE
DIGITAL	42	31.8%
AUGMENTATIVE	70	53%
PARTICIPATIVE	19	14.4%
SOCIAL	1	0.7%
<i>Total</i>	<i>132</i>	<i>100%</i>

Figure 47 shows us both the representation for the value and the percentage of each medium.

We can note that 53% of the interactive apparatuses analysed in our database are of the augmentative type and 32% of digital type. Although digital interfaces are high in number (42), we can see there is a preference for augmentative (70), therefore, more tangible interfaces of communication. In 13 of interactive apparatuses, we have both types of medium available in parallel - not necessarily used at the same time though.

Augmentative interactive apparatuses are of different type of technology, such as:

- Video projection is augmenting the surrounding space around the interactor with image and sound.
- Tangible objects: the interactor will interact with physical objects - augmented with technology such as RFID or accelerometer.
- Augmented reality is augmenting the surrounding space of the interactor via a virtual interface such as a tablet, mobile phone or virtual reality headset.

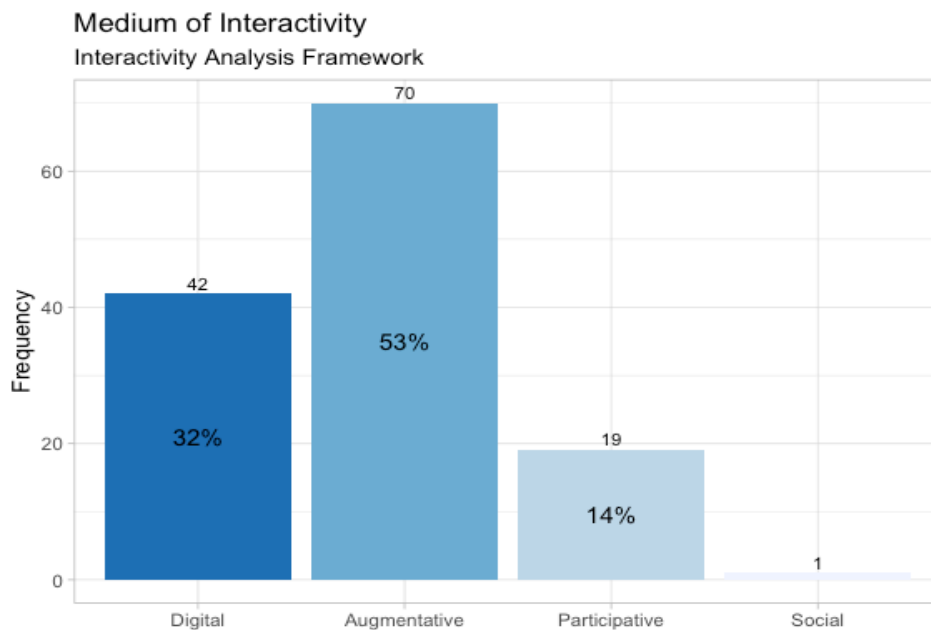


Figure 47 - plot for Medium of Interactivity

7.3.2 Modes of Interactivity: Levels of Coherence

The level of coherence represents, on a 3-level scale, the complexity of “dialogue” that an interactive apparatus is capable. It is worth to note that the level of coherence is not related in any way with the quality of interaction or even the complexity of the interactive apparatus - both on the technology side or the use case scenario.

The level of coherence is a single choice since we are not considering the evolution in time in the current version of the framework but we are rather interested in the main interactive intention.

The following Table 5 aggregates the frequency of each level of coherence for all interactive apparatuses in the database.

Table 5 - Aggregated data for Interactivity Level of Coherence

COHERENCE LEVEL	FREQUENCY	PERCENTAGE
RANDOM	10	9.9%
RESPONSIVE	89	88.1%
INTELLIGENT	2	1.98%
<i>Total</i>	<i>101</i>	<i>100%</i>

As shown in Figure 48, the majority - 88% - of interactive apparatuses are considered as responsive, then 10% is random, and only two interactive apparatuses a considered as prototyping a level of intelligence.

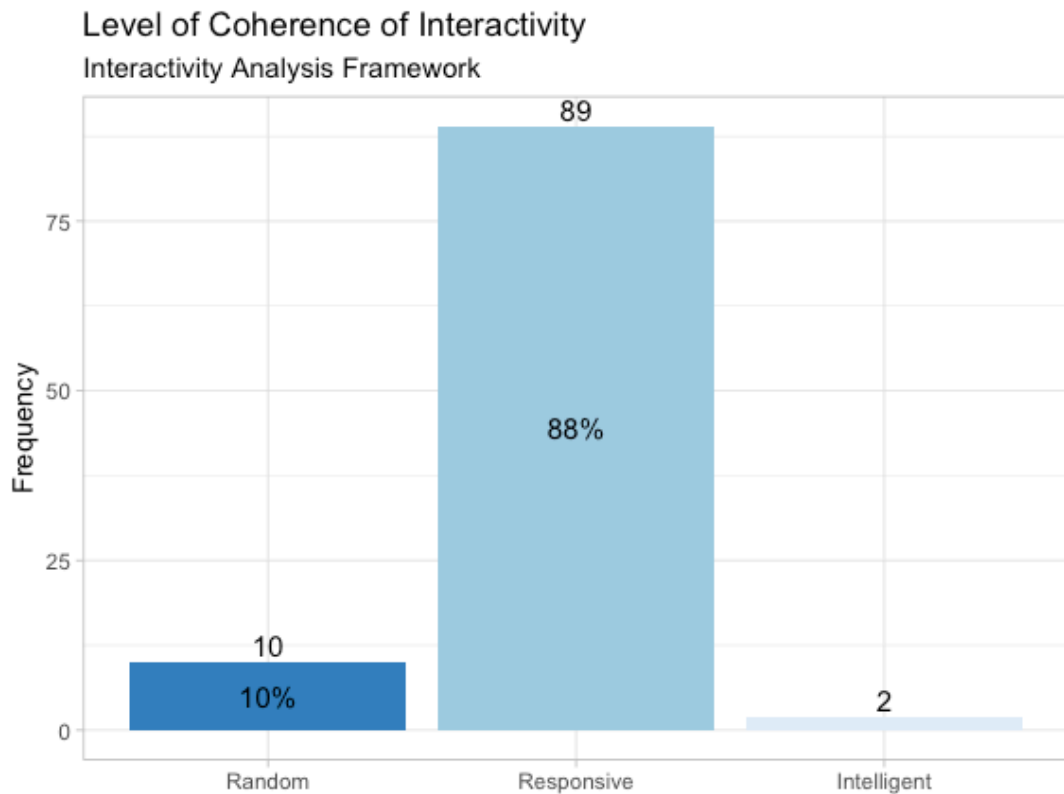


Figure 48 - plot for Level of Coherence

7.3.3 Sensory Representation

As discussed in chapter 5, the sensory representation grid is representing the type of human senses that an interactive apparatus is using across the interaction. As such, we have considered the sensing devices (input) on one side and then the interpreting devices (output) on the other side.

Again, this representation, both on input and output, can be multiple and therefore the total number of sensory representations for both are superior to the total number of interactive apparatuses, as well as they are different between the input and output.

Table 6 - Frequency for Sensing Devices

SENSORY REPRESENTATION	FREQUENCY	PERCENTAGE
VISION	11	7.9%

HEARING	1	0.7%
TOUCH	79	57.2%
LOCATION	33	23.9%
KINAESTHETIC	14	10.1%
GUSTATION	0	0%
OLFACTION	0	0%
Total	138	100%

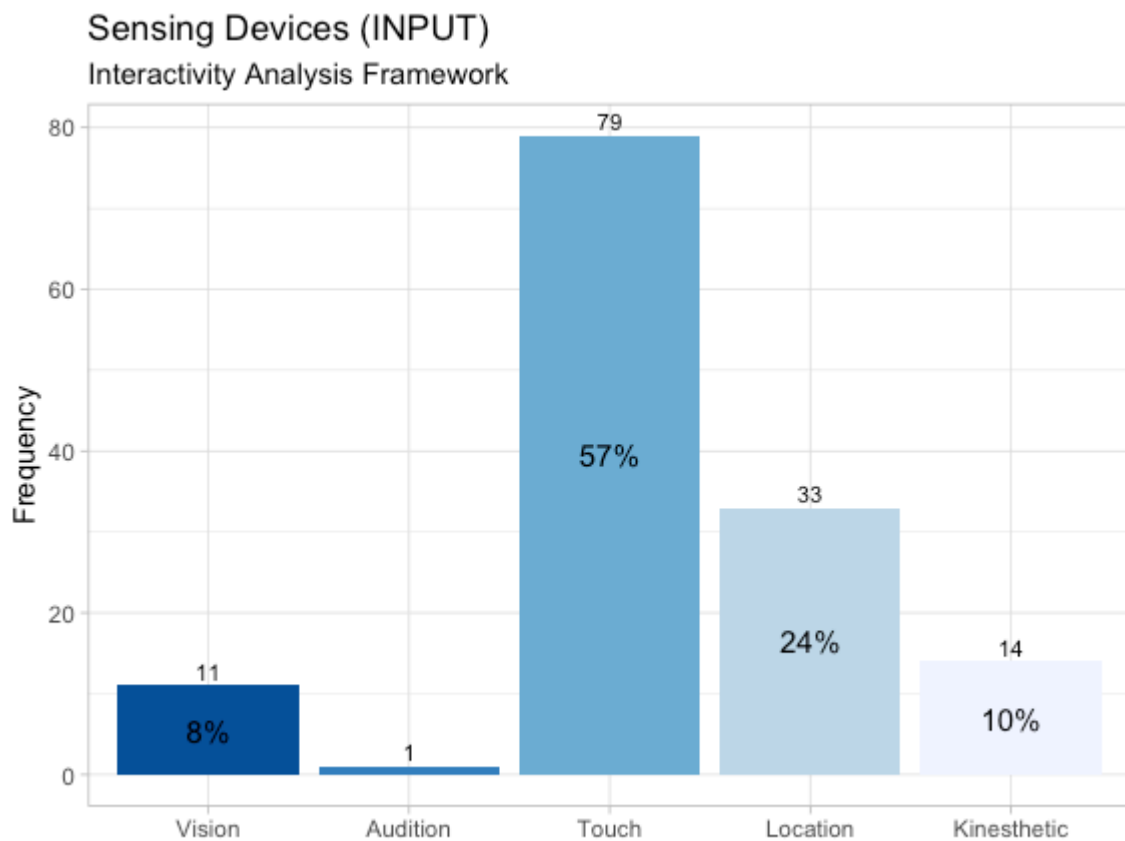


Figure 49 - plot of Frequency of Sensing Devices

Figure 49 is showing the sensing devices representation both in value and percentage. We can identify the touch sense as the most used input devices. 57% of interactive apparatuses have a touch input of some sort. Touch is covering sensing devices such as:

- Applications on a touchscreen, mobile phone or tablet,
- However, also, any physical buttons, whether they are an actual button or any physical surface used as input, like sliding or touching a surface.

Second most used sensing device category is the location for 24%. This category includes sensing devices such as:

- Proximity sensor,
- Location-aware mobile application,
- Wireless technology such as RFID,
- However, also any simple mechanism that can be triggered by an interactor position - a weight sensor on the floor, a light sensor and much more.

This type of sensing devices is usually used to trigger the apparatus and create the condition for the interactivity to engage with the interactor.

We have, at a similar level, both the vision and kinaesthetic devices. Although very different, they can be in some cases very similar in usage: indeed, a motion sensor - kinaesthetic - could also be created with a camera - vision.

Kinaesthetic devices represent 10% of the sensing devices and are detecting the movement of the interactor, and they are in the prototypes analyzed:

- Passive Infrared Sensor (PIR sensor),
- Digital Camera - it could also be devices such as Microsoft Kinect,
- We could also list ultrasonic, microwave or tomographic sensors. However, those sensing devices have not been used in interactive apparatuses in Museomix.

Vision-based devices represent 8% and are:

- Digital camera, whether they are used for photo or video input.

It is interesting to note that only one interactive apparatus was using the hearing sense as a sensor device, namely a microphone. A microphone, as a technology in a digital environment is not a complex system and does not require large bandwidth for data manipulation, therefore we cannot justify the low use of microphones in these interactive apparatuses through the technology point of view. Two factors can identify the reason behind this almost non-usage of the technology:

- Lack of creative scenario to integrate sounds and voices in such a short time in a Museomix,
- In the point of view of the interactor using his/her voice is perceived as an intimate and personal engagement, especially if he or she does not exactly know yet how it is going to be used.

Finally, we can see that both the olfaction and gustation senses are not used at all. Although some technology exists in link with those senses, they are usually not present in the set of technology offered in a Museomix. However, more important than the technology, it is also the psychological aspect of those senses that make them not desirable in an interactive apparatus.

Regarding the interpreting devices (OUTPUT), we can also understand what the most used sensory representation is. Table 7 is showing us the aggregated count for each sense both in frequency (count) and percentage.

Table 7 - Frequency for Interpreting Devices

SENSORY REPRESENTATION	FREQUENCY	PERCENTAGE
VISION	95	53.1%
HEARING	76	42.5%

TOUCH	2	1.1%
LOCATION	1	0.5%
KINAESTHETIC	2	1.1%
GUSTATION	0	0%
OLFACTION	3	1.68%
Total	176	100%

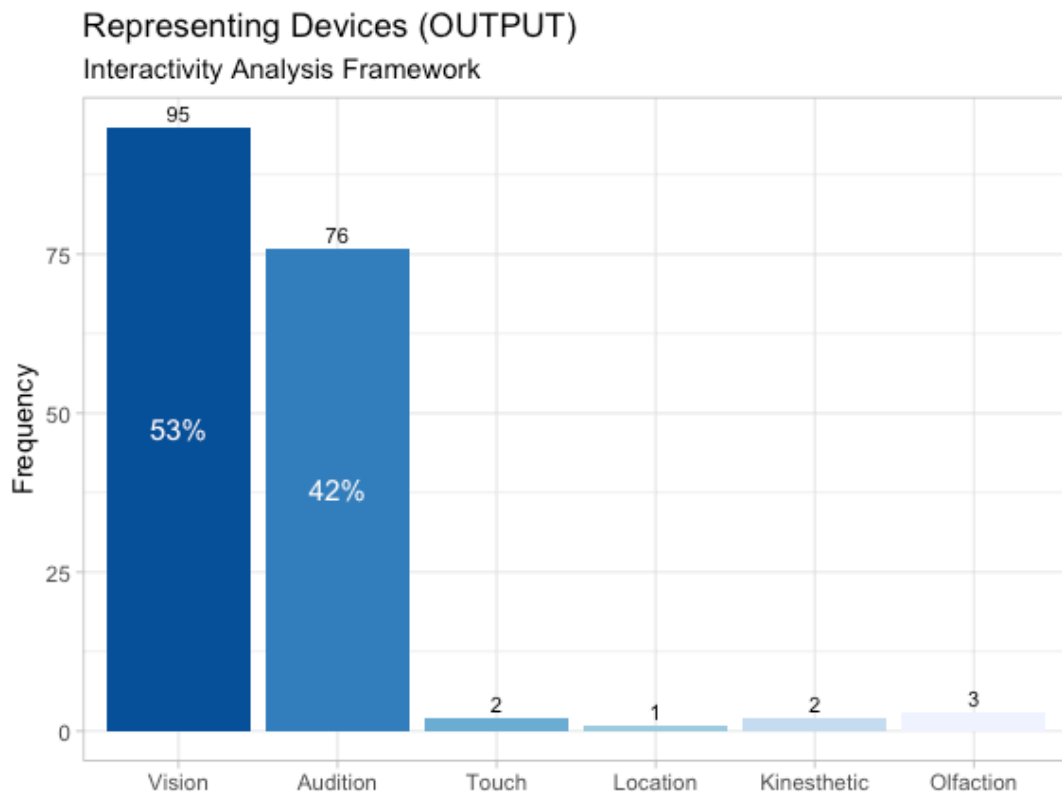


Figure 50 - plot of Frequency of Interpreting Devices

Figure 50 is showing us the frequency of all interpreting devices for our database of interactive apparatuses. We can identify two major interpreting devices, trusting 95% of the usage: the vision for 53% and audition for 42%.

7.3.4 Social Interaction Scale

Regarding the Social Interaction Scale as defined by (Simon, 2010), we have the Table 8 showing us the frequency for each stage that includes interactivity. Indeed, we must point out that the stage 1: “Individual Consumes” cannot be considered as a stage where interactivity can appear. It is the typical visitor experience by watching a painting. Since there is no computer-based apparatus involves as we define the interactivity in chapter 2, we cannot consider this stage as part of an interactive experience.

Table 8 - Frequency of Social Interaction Scale

SOCIAL INTERACTION	FREQUENCY	PERCENTAGE
STAGE 1 Individual Consumes	0	0%
STAGE 2 Individual Interactor	83	78%
STAGE 3 Individual Interactions Aggregated	2	1.88%
STAGE 4 Individual Interactions Used for Social Interaction	20	19%
STAGE 5 Global Social Engagement	1	0.9%
Total	106	100%

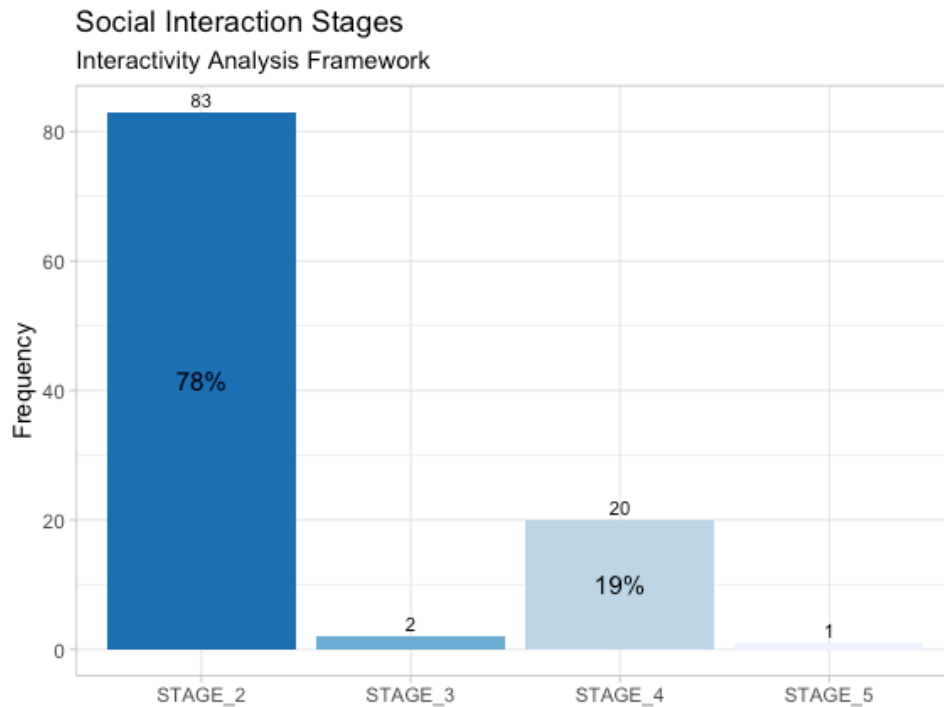


Figure 51 - Frequency for Social Interaction Scale

Although this scale is also of multiple-choices, most of the interactive apparatuses are only fitting in one of the categories of the scale. Indeed, most of them propose only one possible interaction.

We can see from Figure 51 that 78% of interactive apparatuses are proposing individual interactivity, meaning that the interactor is interacting with the apparatus in a one-to-one relationship, nothing is directly shared with other visitors or potential interactors around - often though, visitors can observe part of the interaction.

It is also worth to note that 19% of the interactive apparatuses studied are providing the stage 4 where individual interactions are shared for social use or as in a participative apparatus for modifying the apparatus or its outcome. However, there are only two interactive apparatuses at stage 3, where individual interactions are aggregated to be shared, most probably due to the more complex processing required to get interesting aggregated data.

Finally, there are almost none - only one - stage 5, where the apparatus is used only to engage the public - interactors and visitors - into social interaction. Again, we can most probably explain this limitation with the more complex scenario to create to engage the public into a discussion. We can also conclude that an interactive apparatus is more inclined to reflect on itself rather than opening up its outcome to the human factor.

7.3.5 Museum Taxonomy

The specific classification related to the museum as we defined it in chapter 5 is shown in Table 9. This classification is also of multiple-choice and therefore the total is higher than the total of interactive apparatuses studied, this is normal since some apparatuses can fit in several categories at the same time. For example, a guided-tour system providing real cultural value could also integrate a game or an entertainment option.

Table 9 - Frequency of Museum Taxonomy

MUSEOLOGY	FREQUENCY	PERCENTAGE
GAMIFICATION	61	44.8%
GUIDED TOUR	37	27.2%
VIRTUAL ENVIRONMENT	19	13.9%
PARTICIPATIVE	18	13.2%
SOCIAL INTERACTION	1	0.7%
<i>Total</i>	<i>136</i>	<i>100%</i>

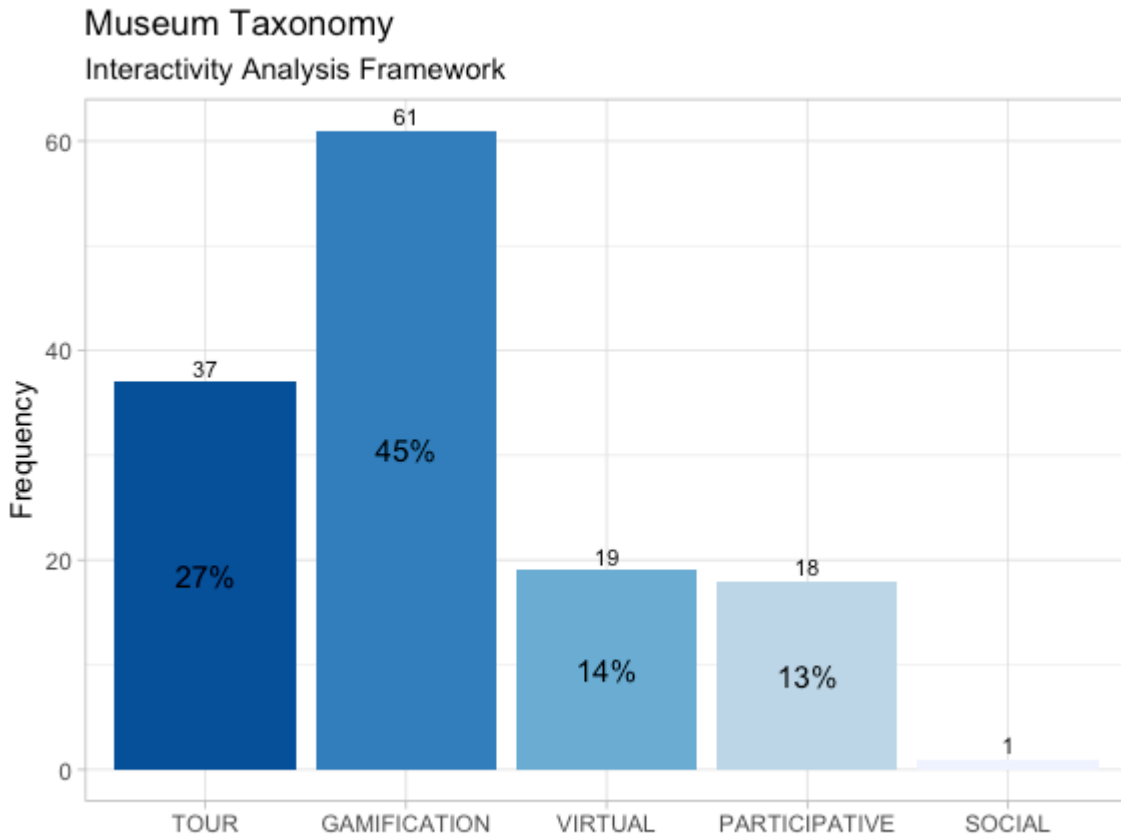


Figure 52 - Frequency of Museum Taxonomy

We can first note that 45% of the interactive apparatuses studied are of the type of gamification. As previously explained in chapter 5, gamification can include well-understood game mechanics as well as more complex entertainment systems mixing culture knowledge and broader topics to keep the interactor interested.

Secondly, the type of guided-tour is present at 27%. Guided-tour systems are a traditional activity for a museum, and we can find it also in interactive apparatuses. Although the majority of these interactive apparatuses are not traditional on the user's case, they are nonetheless considered as guided-tour for their cultural properties and the intention of the creators.

Regarding the virtual environment, we found 14% of interactive apparatuses to belong to this category, and this is most probably a category that will grow in the coming years due to the

more abundant availability of technology and its lower price and ease of use to create content with.

Participative apparatuses are found at 13%. The narrative behind a participative apparatus is always a risk for a museum, and although they can potentially encourage social interactions, they are more complex to conceive and develop.

7.4 Discussion

We have looked above to the individual variable of our framework to not only validate our framework but also to give us an initial understanding of Museomix events.

In this section, we will look at the correlation between some of our variables to understand if we can detect some valuable patterns to give more insight into our initial analysis above.

There are a few notes to make regarding these plots:

- Since Museomix started in France and has usually more than three museums in France every year engaged in the event, it is evident that the size of the circles on the plot will be more prominent for this country. Therefore, we are not interested in understanding the simple distribution by country.
- These plots are not including the two personal exhibitions in Macau; we are here focusing on Museomix analysis since they are currently the vast majority of interactive apparatuses in our dataset and are two personal exhibitions were not developed with a hacking methodology. Therefore, we will not consider it for our present analysis.

The first analysis is looking at the modes of interactivity and particularly the medium, which includes: Digital, Augmentative, Participative, Social.

Since we are mainly dealing with categorical variables, we decided to use a “balloon plot” representation. Balloon plot is a graphical matrix where each cell contains a dot whose size reflects the relative magnitude of the corresponding component. It is convenient to represent a particular distribution of categorical variables.

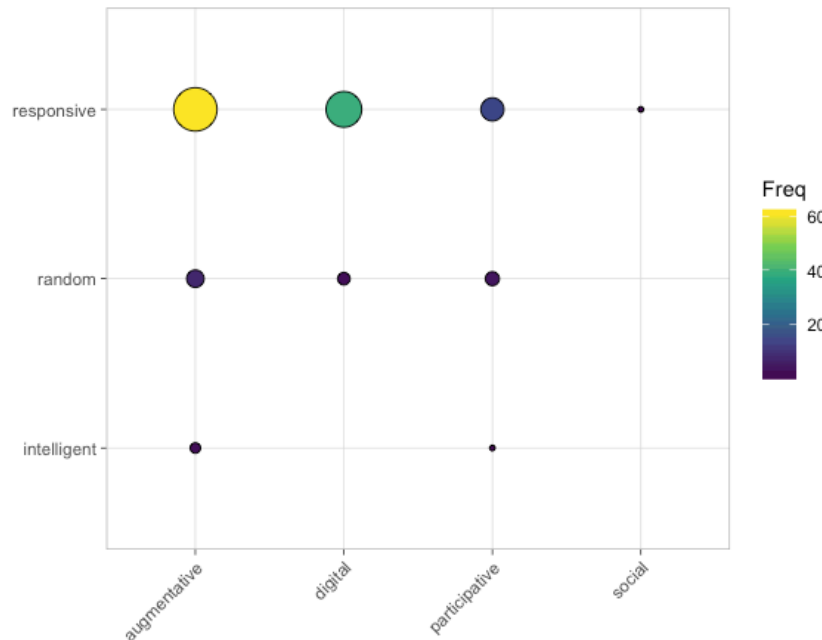


Figure 53 - Medium and Coherence Distribution

In Figure 53, we are representing the number of each medium in each coherence level available. As we have discussed earlier, we know that the majority of mediums are of digital and augmentative, and that the majority of coherence level is of responsive, we can identify the larger circles (also named balloons or bubbles) representing this correlation. We can see that, whatever the medium is, the responsive coherence level is always the most represented; therefore, we can suppose that those two variables are entirely independent of each other.

Figure 54 is showing us the medium versus the country of origin of the interactive apparatus.

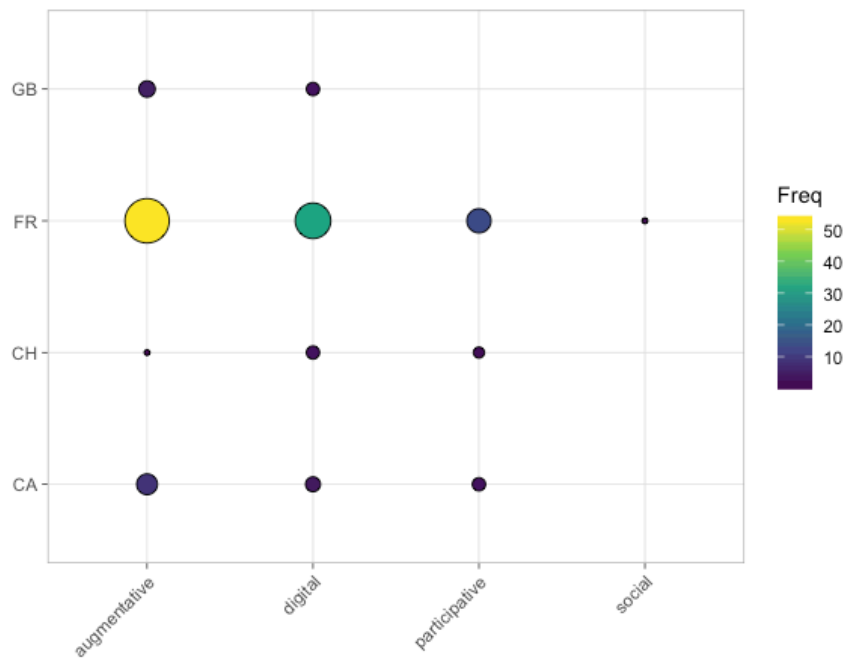


Figure 54 - Medium and Country Distribution

What this chart is showing us is what type of medium is more prevalent in each country. To that regard, we can see that for France, the United Kingdom and Canada, the most used mediums are:

1. Augmentative,
2. Digital,
3. Participative.

However, we can see a difference in Switzerland where the order is:

1. Digital,
2. Participative,
3. Augmentative.

This indicator could show us that some country-specific cultural values might influence the type of medium. However, our dataset is only including one Museomix edition in Switzerland - 2014 - representing five prototypes. To confirm such a tendency, we would like in the future

to integrate more recent Museomix editions where some museums in Switzerland participate as well.

Figure 55 is showing the medium distribution per year - again between 2011 and 2014, which is the years we studied Museomix prototypes.

Although the proportion of each medium can slightly change every year, they always remain in the same order of frequency, namely: Augmentative first, Digital second, then Participative and finally Social. This consistency might show us a limitation in the hacking methodology and its application in Museomix; this would have to be studied further in the future with a larger dataset and interviews with Museomix participants.

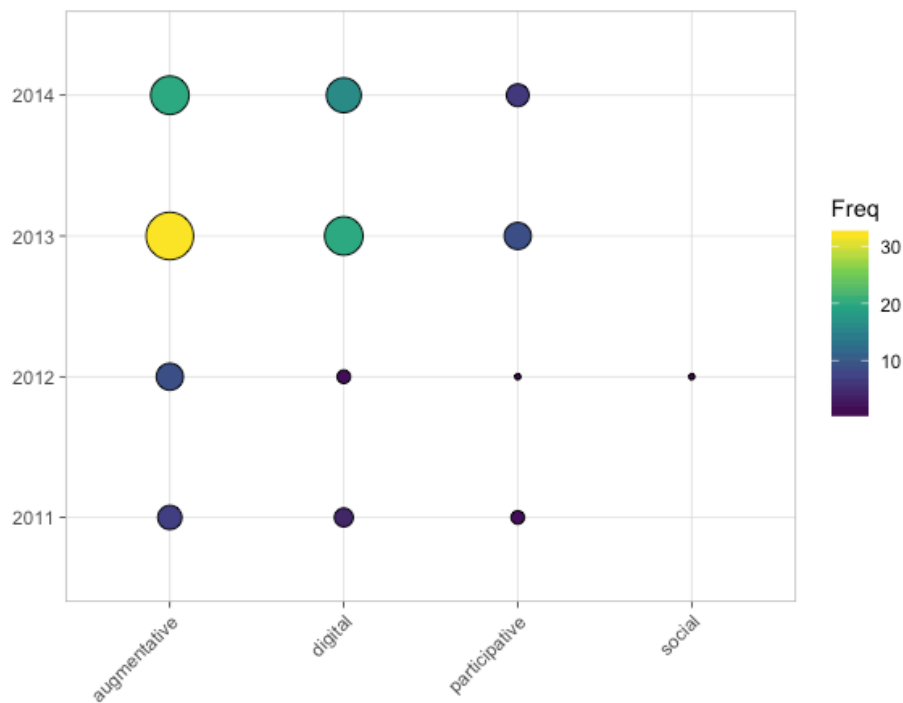


Figure 55 - Medium and Year Distribution

Finally, Figure 56 shows us the medium across each stage of the Social Interaction Scale.

The majority of interactive apparatuses are in stage 2 - Individual Interaction - for both the Augmentative and the Digital medium; this means that a one-to-one interaction is the most prevalent type in interactive apparatuses. The second batch is in stage 4 - Individual Interactions are shared.

However, for the Participative medium, the predominant stage is the number 4 - Individual interactions shared; this is telling us that most of the interactive apparatuses that are participative are mainly sharing the user interactions with the surrounding public, but we almost do not have any stage 3. Stage 3 could also be seen as participative but what is shared is only some sort of aggregated information based on the interactions. Again, this indicates some limitations in the creative process of the methodology used in such type of events.

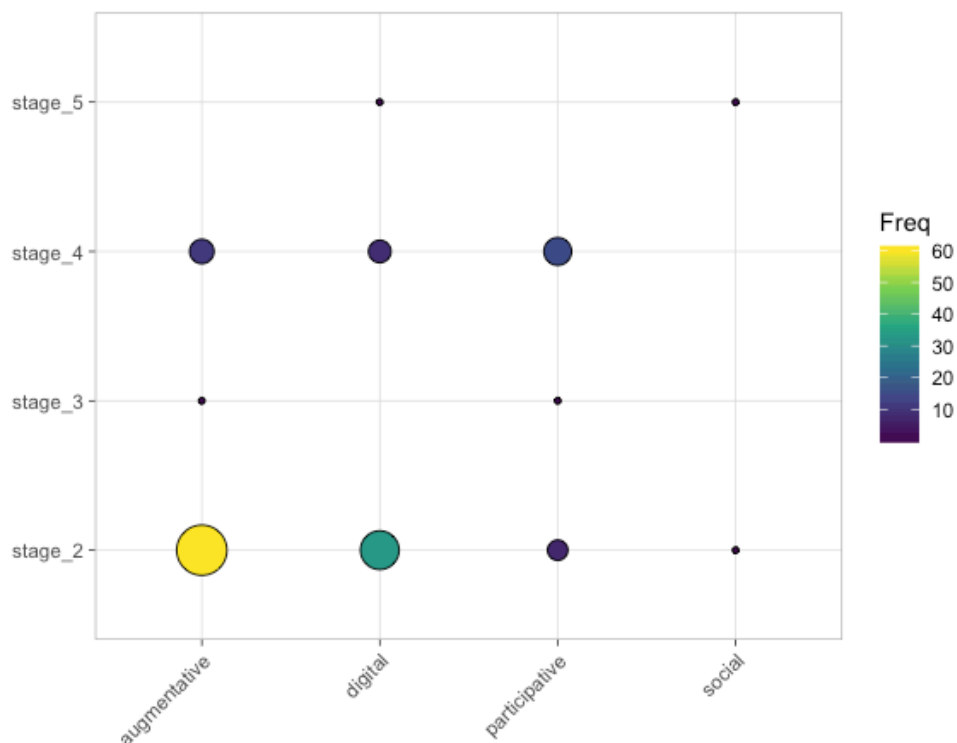


Figure 56 - Medium and Social Interaction Scale Distribution

The Sensory Representation is composed by the Sensing Devices (INPUT) variable as well as Interpreting Devices (OUTPUT). Figure 57 shows both parts in a balloon plot, and as we mentioned earlier, the majority of interactive apparatuses have as sensing device with a touch interface. Since we are in the presence of computer-based systems with often mobile or web applications, we can understand that this sense is the most represented. However, the sense of touch is not only used with applications, but it can also be used with tangible objects that are interfaced with a computer. Moreover, we can also note that touch sensing devices are linked with all interpreting devices: touch, vision, audition, location, kinaesthetic and olfaction.

Regarding the interpreting devices, we can see the lines representing the vision - screen or projection - and the audition - speakers - that are the most used as an output device. It is interesting to note that both interpreting devices - vision and audition - are linked with the sensing devices in a very close proportion; indeed, we can see in the same order:

1. Touch
2. Location
3. Kinaesthetic
4. Vision
5. Audition

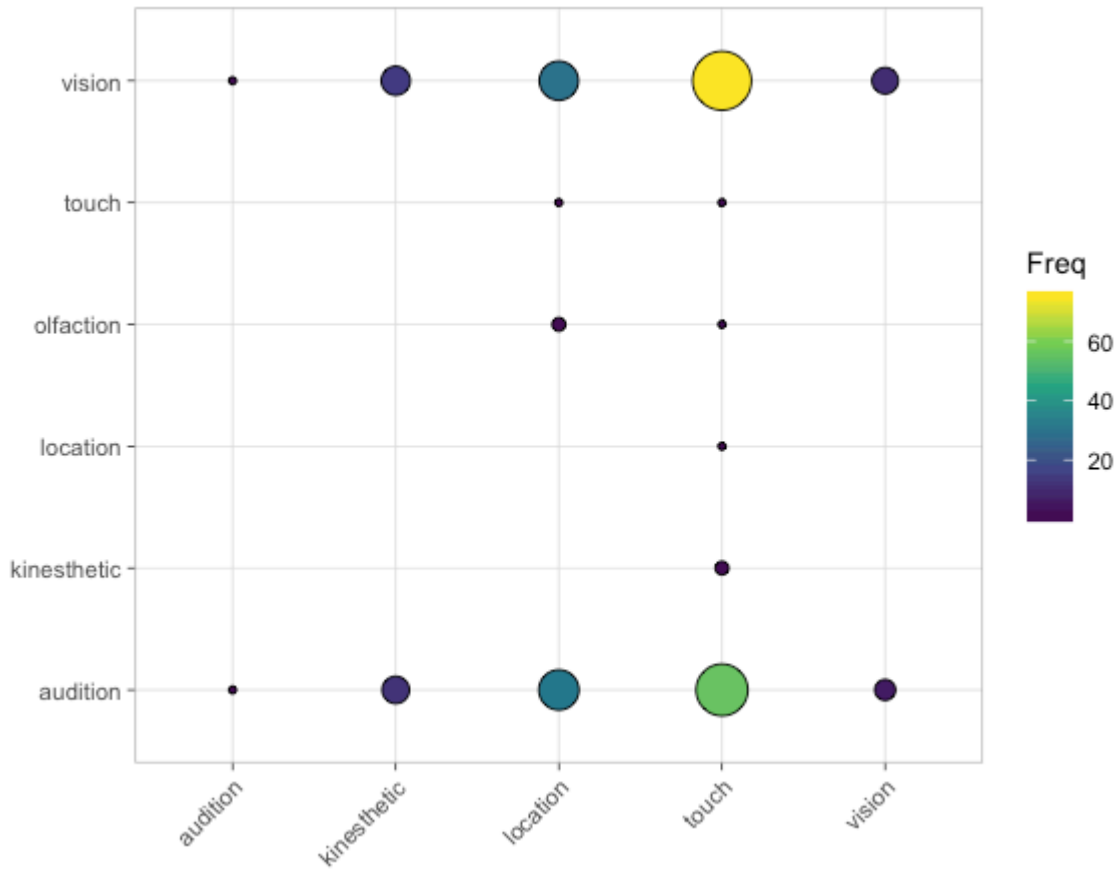


Figure 57 - Sensing Devices and Interpreting Devices Distribution

This representation can be useful as well to see how we can improve the distribution of devices, not only for a better balance and more diverse experience but also as a means to improve the inclusivity of the interactive apparatuses.

Figure 58 shows the social interaction scale - stage 1 to 5 - with the country - left plot - and with the Museomix edition year - right plot.

While we can note that the stage 2 - individual interactor - is present in all countries and years, we can see that stage 4 is not present everywhere: it is not present in the United Kingdom and was not present in 2012 - only one museum that year.

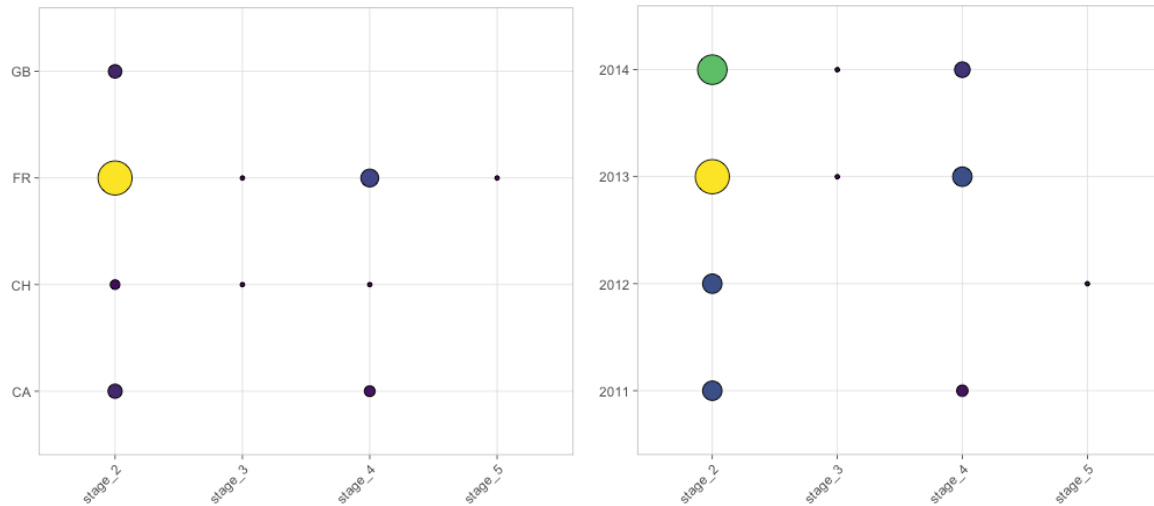


Figure 58 - Social Interaction Stages by countries and years

Figure 53 shows the museum taxonomy per country and the museum taxonomy per year of Museomix editions studied. As mentioned earlier, we can identify the two major types of interactive apparatuses: Gamification and Guided-Tour. However, the distribution between each type is different from country to country and year. We can note the following:

- While France, Switzerland and Canada have more apparatuses in the gamification type, the United Kingdom has more Guided-Tour type than games.
- Participative and Virtual Environment apparatuses have emerged only in 2013.

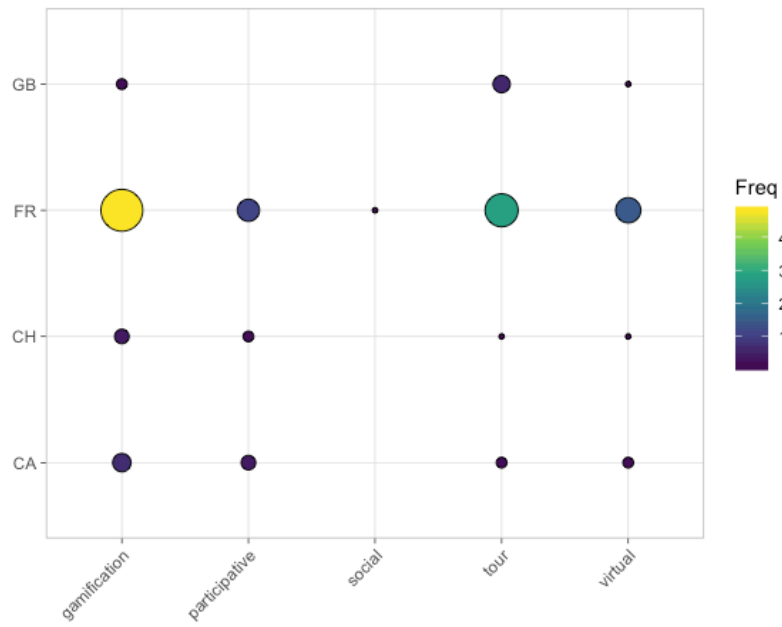


Figure 59 - Museum Taxonomy by Country

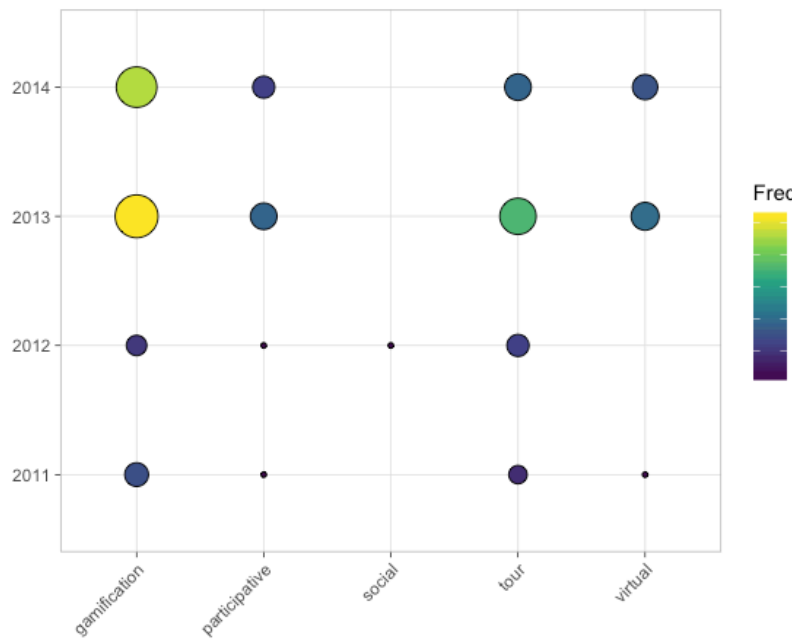


Figure 60 - Museum Taxonomy by Year

7.5 Conclusion

In this chapter, we have presented an analysis of our dataset collected from several Museomix editions. The Multivariate Analysis Framework for Interactive Apparatus has been used to collect data from more than one hundred apparatuses over the year 2011 to 2014 in different Museomix events as well as on two personal exhibitions in 2016 and 2019.

We can now see that the proposed framework allows us:

1. To classify an interactive apparatus with several criteria and perspectives - variables - to understand its intrinsic properties,
2. To analyse the dataset - or a subset of it - to give us a global perspective on all the interactive apparatuses.
3. To compare interactive apparatuses by their properties.

We have been able to highlight essential correlations between some of our variables as well as identify some tendencies and limitations of such type of creative marathon.

CHAPTER VIII

Conclusions

8.1 Introduction

In this chapter, we summarise the most significant outcomes of our research and contributions made to the different fields intersected during the study.

Due to the experimental nature of the Museomix event, we cannot aspire to a yes or no answer to the interactivity in museums through a hacking approach. Instead, we hope to contribute with a framework that we consider to be an initial step in the direction of a better understanding of interactivity and a repeatable process to understand and evaluate interactive apparatus properties.

Chapter 2 introduces the concept of interactivity and how we can understand it as a spectrum rather than a monolithic definition for a specific case. The interactivity is an inherent property of an apparatus, whether there is or not an interactor. Finally, we demonstrated that the interactive property is composed by different attributes, developed in chapter 5.

Chapter 3 introduces the term “hacking”. First, we looked at the origin, rooted mainly in the early days of the computer era, we then identified how this approach sometimes rebellion and sometimes amusement has evolved into a bottom-up methodology for the creative process. This methodology was used to create all interactive apparatuses in our dataset - except for two.

Chapter 4 places the museum in its historical context and its evolution since the birth of computer-based systems. We also described museums challenges and how they are facing them with traditional methods.

Based on the previous chapters, Chapter 5 introduces the Multivariate Analysis Framework for Interactive Apparatus. This framework is our contribution to understand and analyse an

interactive apparatus. We also introduce in this chapter a web application developed during our study to collect, present and analyse interactive apparatus based on the theoretical framework.

Chapter 6 introduces the creative process of Museomix as well as a detailed explanation of the two personal exhibitions.

Chapter 7 analyses our dataset of one hundred and one interactive apparatuses through descriptive statistics and graphical representation to understand patterns, correlation and limitations of this type of creative process.

8.2 Summary Conclusion

Our initial objectives were to identify the attributes of the interactivity and how we could measure them and classify any interactive apparatuses by applying to it a framework.

The first conclusion is that we can understand interactivity by proposing a new paradigm where:

- Interactivity is understood here as a computer-based apparatus with capabilities to understand and communicate - to a certain extent - with an interactor.
- Interactivity is an intrinsic property of an interactive apparatus,
- Interactivity exists per se; the audience engagement is not required - not that it is not essential, but it exists without the audience.
- A series of four attributes can describe the interactive property: Modes of Interactivity (Medium and Level of Coherence), Sensory Representation and Social Interaction Scale.

The majority of interactive installation art and interactive apparatuses are created and tested only with - and for - the engagement perspective. Stakeholders - museums and researchers - are interested, and for good reasons, in evaluating how an audience interacts with their apparatus. However, studying only the engagement can seldom present reproducible conclusions since the context might be diverse: whether by cultural environment, education level, creative intention or the physical environment and so many more.

Since we have defined the interactivity by its property, the second conclusion is that we are therefore able to propose a framework to classify, evaluate and visualise any interactive apparatus. The framework named the Multivariate Analysis Framework for Interactive Apparatus - MAFIA - has been developed and implemented into an application to allow us to apply it to all the interactive apparatuses from Museomix from 2011 to 2014 as well as two personal exhibitions.

The objective of our work is to propose a standardised framework to understand any interactive apparatus in a repeatable manner. We have, therefore eliminate the audience engagement variable for our initial work. Once our framework will be more experimented and completed, we will be able to propose a second phase to understand the audience engagement and relate it to the initial framework.

The third conclusion is related to the hacking methodology, particularly in museums, since it is our specific context in this work. With an event such as Museomix, we can see how this new approach to imagine new mediation for a museum can be a rich experience for the participants but also the museum and its staff. This creative marathon is a source of innovative prototypes for a museum.

However, we also have identified that there are limitations to this type of creative process, and of course, a museum could not rely only on this. We have identified some tendencies that can limit the impact of such methodology, namely:

- One-to-one interaction is the majority of interactive apparatuses. However, museums are usually interested in creating more social activities and as such, reaching a higher level of the Social Interaction Scale.
- There is no intelligent interactive apparatus - except for two attempts. According to the evaluation, the modes of interactivity are either “random” or “responsive” for the Level of Coherence. We can explain this restriction due to 1) the complexity of such type of technology - which is getting easier every year, and, 2) the complexity to imagine and create such a scenario, particularly in less than three days within a team that need to discuss each step - sometimes the vision of one leader can be more efficient.
- Many of the interactive apparatuses created within this methodology are game-based. One reason for this could be that gamification is a popular paradigm for educational purposes and therefore, can be natural to many participants coming from multimedia or technological background. Another explanation can also be that from the very beginning of Museomix, participants are encouraged to take pleasure, to play with the environment of the museum. We could say there is a conditioning of participants that can probably bias them toward gamification.
- Another pattern that we can identify is a tendency to create conventional interactive apparatus; conventional in this context meaning apparatus that is not creative nor

innovative but repeat one or several features from an existing apparatus. Here we are touching a creative limitation of a team. The support of more experienced persons from the organisation can overcome this limit.

At the time to conclude our work, we recognise that we have achieved a step in a broad research field. We believe our first results are encouraging and pointing us toward a better understanding of interactive apparatuses in museums. These results are by no means closed to discussions; on the contrary, we are encouraging new perspectives to continuously improve the framework and the understanding of both interactive apparatus and the hacking methodology.

8.3 Future Work

Following the work presented in this thesis, we are presenting in this section several directions to further the research.

8.3.1 Cataloguing

The most apparent direction will be to continue the work of cataloguing interactive apparatuses with the framework. Museomix edition from 2015 to 2018 contains now one hundred twenty-five prototypes that can be a tremendous improvement in our understanding of such event and its relation with interactivity.

8.3.2 Extending the Framework

The second work will be to improve the Multivariate Analysis Framework for Interactive Apparatus. Following new discussions, we should be able to refine the framework to make it more robust and comprehensive. After using the framework ourselves to create our existing

dataset, we believe there is room to improve the framework further both in the number of criteria and on the independence of variable.

One aspect that we did not integrate into our work is the notion of sequential and parallel time. Indeed, as we mentioned in chapter 2, the interactivity property can evolve and modify itself - or under the interactor intervention. We think it would be possible to integrate a sequential and parallel map to indicate the possible different state of the interactivity in time.

We have mentioned the technology used in interactive apparatuses, and we have some basic notes about it in the framework. However, a more comprehensive classification of the technology could be interesting at several levels: first to identify the evolution of technology usage in time, secondly to compare and generate statistics on technology or identify technology with high interactive potential that is not enough represented. Such classification is not as trivial as it seems since we would have to decide on the level of details we want to integrate - for example, do we need to know whether the video projector has a lamp or a laser as technology? Another aspect that we did not consider is how much an interactive apparatus is inclusive. The inclusivity refers here to interactors with special needs such as visually impaired people and more. We want to consider to extend the Sensory Representation in our framework to include some element to help to identify to what extent an interactive apparatus is inclusive, or at least in which area.

Finally, we think that integrating within the framework the creative intention could also bring a new aspect to the analysis. We could define the creative intention by verbs such as: inform, promote, marvel.

The implementation of these features in future research will increase the validity of the results achieved through this current study and open new understandings.

8.3.3 Extending the Context

The context of this research was focusing on museums participating in a Museomix edition. We believe the framework could be easily extended to other types of interactive apparatus, such as:

- Apparatus developed with a hacking methodology similar to Museomix but not in a museum. Indeed, in the last five years, we have seen new “mix” developing outside museum, such as:
 - Gare Remix, in a train station,
 - HackMyChurch, in a church,
 - Mont-Blanc Lab, in the French Alps mountain,
 - Dansathon, in a dance theatre
- Interactive Installation Art, interactive exhibits not necessarily developed in a hacking methodology but presenting an interactive component.

8.3.4 Relation to the Engagement

We have stated that our research and framework are focused on interactivity as a property of an apparatus; without considering the engagement. This condition was necessary to work on the inherent attributes of an interactive apparatus.

The next step would be to identify a possible extension of the framework to interface with audience engagement. Frameworks for audience engagement have been developed in the past, such as the Pleasure Framework (Costello, 2007) or (Nam, Park, & Verlinden, 2009). We are interested to see how a convergence with our framework could help a holistic approach from the apparatus to the engagement.

As stated by Bilda, the “level of engagement with an interactive artwork depends on various factors such as aesthetic satisfaction, and how the audience constructs meaning, pleasure and enjoyment. Evaluating such experiences remains an open research problem” (Candy & Bilda, 2009). We could not agree more.

8.4 Personal Conclusion

As a researcher, we acknowledge that there is an open research field in front of us, and we hope to have the opportunity to continue this work. We are interested in pushing forward the research in the following areas:

- To conceptualise the interactivity model introduced in this work.
- To extend the Multivariate Analysis Framework by both enlarging the dataset and introducing new variables.

As a professor, we believe we can extend our work in two directions:

- To experiment with new installation art and interactive apparatuses and encourage students to explore and integrate the interactivity in their design.
- To expend the research on hacking and experiment it as a pedagogical tool with students.

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APPENDIX 1

Web Application to manage the Interactivity Analysis Framework database

Below we provide the main part of the code, for the working application please refer to the Github repository at <https://github.com/gestadieu/ias-backend>

package.json

```
{
  "name": "backend",
  "version": "1.0.0",
  "description": "backend for the Interactivity Analysis Framework",
  "main": "index.js",
  "scripts": {
    "dev": "nodemon index.js"
  },
  "keywords": [
    "interactivity",
    "framework"
  ],
  "author": "Gerald Estadieu",
  "license": "MIT",
  "dependencies": {
    "express": "^4.17.1",
    "nedb": "^1.8.0",
    "pug": "^2.0.4"
  },
  "devDependencies": {
    "http-server": "^0.11.1",
    "live-server": "^1.2.1",
    "nodemon": "^1.19.1"
  }
}
```

index.js

```
const express = require('express');
```

```

const app = express();
const Datastore = require('nedb');
const readline = require('readline');
const fs = require('fs');
const pug = require('pug');

const port = 3000;
app.listen(port, () => console.log('listening on 3000'));
app.set('view engine', pug);
app.use(express.static('public'));
app.use(express.json({
  limit: '1mb'
}));
app.use(express.urlencoded({
  extended: true
}))

const db = new Datastore({
  filename: 'database.db',
  timestampData: true
});
db.loadDatabase();

app.get('/api', (request, response) => {
  const filters = request.query;
  const find = {};
  let total = 0;

  // Sorting
  const sort = {};
  const field = filters['sort'] ? filters['sort'] : 'createdAt';
  const order = filters['order'] ? filters['order'] : -1;
  sort[field] = order;

  // Pagination
  const skip = filters['skip'] ? filters['skip'] : 0;
  const limit = filters['limit'] ? filters['limit'] : 0;

  // search specific field
  const fieldname = filters['field'];
  const fieldvalue = filters['value'];

```

```

if (fieldname && fieldvalue) {
    find[fieldname] = fieldvalue;
}

// Search keywords
const search = filters['search'] ? filters['search'] : '';
if (search) {
    find['$where'] = function () {
        const obj = this;
        const keys = ['name', 'year', 'place', 'country', 'typeofplace',
'type', 'interactivity'];
        let result = false;
        keys.forEach(elt => {
            const rs = (obj[elt]) ? obj[elt].includes(search) : false;
            if (rs) {
                result = true;
                return rs;
            }
        });
        return result;
    }
}

// total number
db.count(find, (err, tt) => {
    total = tt;
});

db.find(find).sort(sort).skip(skip).limit(limit).exec((err, docs) => {
    if (err) {
        response.end();
        return;
    }
    const rs = {
        count: docs.length,
        total,
        page: skip + 1,
        docs
    };
    response.json(rs);
})

```

```

});

app.get('/api/:id', (request, response) => {
  db.findOne({
    _id: request.params.id
  }, (err, doc) => {
    response.json(doc);
  });
});

// Create a new document in database
app.post('/api', (request, response) => {
  const data = request.body;

  // make sure we always have an array
  ['medium', 'input', 'output', 'sociali', 'museum'].forEach(elt => {
    if (typeof data[elt] === 'string') {
      data[elt] = [data[elt]];
    }
    if (!data[elt] || data[elt] === undefined) {
      data[elt] = [];
    }
  });

  // save data ind db and send back
  db.insert(data);
  response.json(data);
});

/*
  Export database to a json format directly readable by R for analytic purpose
  - add comma after each document
  - create a global array with all documents
*/
app.get('/db4R', (request, response) => {
  const jsonfile = '../R_analysis/database.json';
  let jsonlines = '';
  let rl = readline.createInterface({
    input: fs.createReadStream('database.db')
  });

```

```

});

// let line_no = 0;
rl.on('line', line => {
  line = line.trim();
  jsonlines += `${line},\n`;
});

rl.on('close', () => {
  jsonlines = `[${jsonlines.slice(0, jsonlines.length - 2)}]`;
  fs.writeFile(jsonfile, jsonlines, err => {
    if (err) {
      console.log('on close database', err);
    }
    response.json({
      status: 'success',
      message: 'Database exported!'
    });
  });
});
})

app.get('/', (request, response) => {
  db.find({}).sort({
    year: -1,
    city: 1,
    name: 1
  }).exec((err, docs) => {
    if (err) {
      response.end();
      return;
    }
    const rs = {
      count: docs.length,
      total: docs.length,
      page: 1,
      docs
    };

    response.render('list.pug', {
      data: rs

```

```

        });
    })
})

/*
  Display a page with details of an Interactive Apparatus
*/
app.get('/show/:id', (request, response) => {
  db.findOne({
    _id: request.params.id
  }, (err, doc) => {
    response.render('show.pug', {
      title: `Interactive Apparatus - ${doc.name}`,
      doc
    })
  });
})

/*
  display the form to add a new Interactive Apparatus
*/
app.get('/add', (request, response) => {
  // doc = new Apparatus();
  response.render('form.pug', {
    doc: {}
  });
})

/*
  add a new Interactive Apparatus into the database
*/
app.post('/new', (request, response) => {
  const data = request.body;

  // make sure we always have an array (even empty, for R statistics)
  ['medium', 'input', 'output', 'sociali', 'museum'].forEach(elt => {
    if (!data[elt] || data[elt] === undefined) {
      data[elt] = [];
    }
    if (typeof data[elt] === 'string') {
      data[elt] = [data[elt]];
    }
  });
});

```

```

    }
  });

  // save data ind db and send back to the detail page
  db.insert(data, (err, doc) => {
    if (!err)
      response.redirect(`/show/${doc._id}`);
  });
});

/*
  edit an existing Interactive Apparatus
*/
app.get('/edit/:id', (request, response) => {
  db.findOne({
    _id: request.params.id
  }, (err, doc) => {
    response.render('form.pug', {
      doc
    })
  });
});

app.post('/update/:id', (request, response) => {
  const data = request.body;

  ['medium', 'input', 'output', 'sociali', 'museum'].forEach(elt => {
    if (typeof data[elt] === 'string') {
      data[elt] = [data[elt]];
    }
    if (!data[elt] || data[elt] === undefined) {
      data[elt] = [];
    }
  });
});

db.findOne({
  _id: request.params.id
}, (err, doc) => {
  let newDoc = {
    ...doc,
    ...data
  }

```

```
};
db.update({
  _id: newDoc._id
}, newDoc, {}, (err, d) => {
  response.redirect(`/show/${newDoc._id}`)
})
});
})
```

APPENDIX 2

R script for Descriptive Statistics

```
# =====  
# Statistical Analytics for the  
# Multivariate Analysis Framework for Interactive Apparatus - MAFFIA  
# =====  
  
# loading libraries  
#library(tidyverse)  
library(dplyr)  
library(ggplot2)  
library(tidyr)  
library(forcats)  
library(scales)  
library(ggpubr)  
library(leaflet) # used for mapping  
library(jsonlite) # used for JSON import  
  
# load the database of interactive apparatuses  
apparatus <- as_tibble(fromJSON('./database.json'))  
# apparatus <- as_tibble(fromJSON('http://localhost:3000/db4R'))  
View(apparatus)  
  
museomix <- apparatus %>%  
  filter(country!='MO')  
# =====  
# 1. Simple Analytics  
# =====  
  
# apparatus per country  
apparatus %>% count(country) %>% arrange(desc(n))  
# same as apparatus %>% group_by(country) %>% summarise(n=n()) %>% arrange(desc(n))  
  
# apparatus per city  
apparatus %>% count(city) %>% arrange(desc(n))  
  
# =====  
# 2. Graphics about Interactivity  
# =====  
theme_set(theme_light()) # theme_set(theme_bw())  
  
# MEDIUM  
med <- c("Digital", "Augmentative", "Participative", "Social")  
  
apparatus %>%
```

```

unnest(medium) %>%
count(medium, sort = TRUE) %>%
mutate(percentage= n/sum(n))

apparatus %>%
  unnest(medium) %>%
  mutate(
    medium = tools::toTitleCase(medium),
    meds = factor(medium, levels = med)) %>%
  ggplot(aes(x=meds, fill=meds)) +
  geom_bar() +
  geom_text(aes(label=..count..,stat="count",position=position_nudge(), ,vjust=-0.4,
size=3, colour = "black")) +
  geom_text(aes(label=ifelse(..count..>5,paste0(round(..count../sum(..count..) *
100,0),"%"),""),stat="count",position = position_stack(vjust = 0.5), size=4,
color="white")) +
  labs(x="", y="Frequency", title="Medium of Interactivity", subtitle = "Interactivity
Analysis Framework") +
  theme(legend.position = "none") +
  # scale_fill_grey(start = 0, end = .9)
  scale_fill_brewer(direction=-1)

# COHERENCE
coh <- c("Random", "Responsive", "Intelligent")

apparatus %>% select(coherence) %>%
  count(coherence, sort = TRUE) %>%
  mutate(percentage=n/sum(n))

apparatus %>%
  mutate(
    coherence = tools::toTitleCase(coherence),
    coh = factor(coherence, levels = coh)) %>%
  ggplot(aes(x=coh, fill=coh)) +
  geom_bar() +
  geom_text(aes(label=..count..,stat="count",position=position_nudge(), ,vjust=-0.3,
size=4, colour = "black")) +
  geom_text(aes(label=ifelse(..count..>2,paste0(round(..count../sum(..count..) *
100,0),"%"),""),stat="count",position = position_stack(vjust = 0.5), size=4,
color="black")) +
  labs(x= "", y = "Frequency", title = "Level of Coherence of Interactivity", subtitle
= "Interactivity Analysis Framework") +
  theme(legend.position = "none") +
  scale_fill_brewer(direction=-1)

```

```

# INPUT / OUTPUT
senses <- c("Vision", "Audition", "Touch", "Location", "kinaesthetic",
"Olfaction","Gustation")

apparatus %>%
  unnest(input) %>%
  count(input, sort = TRUE) %>%
  mutate(percentage= n/sum(n))

apparatus %>%
  unnest(input) %>%
  mutate(
    input = tools::toTitleCase(input),
    hsenses = factor(input, levels = senses)) %>%
  ggplot(aes(x=hsenses, fill=hsenses)) +
  geom_bar() +
  geom_text(aes(label=..count..),stat="count",position=position_nudge(), ,vjust=-
0.4, size=3, colour = "black") +
  geom_text(aes(label=ifelse(..count.. > 5, paste0(round(..count../sum(..count..) *
100,0),"%"),""),stat="count",position = position_stack(vjust = 0.5), size=4,
color="black") +
  labs(x="", y="Frequency", title="Sensing Devices (INPUT)", subtitle =
"Interactivity Analysis Framework") +
  theme(legend.position = "none") +
  scale_fill_brewer(direction=-1)

# apparatus %>%
#   unnest(output) %>%
#   count(output, sort = TRUE) %>%
#   mutate(percentage= n/sum(n)) %>%
#   arrange(desc(n)) %>%
#   ggplot(aes(x=fct_reorder(output,n, .desc=TRUE), y=n)) +
#   geom_col()

apparatus %>%
  unnest(output) %>%
  mutate(
    output = tools::toTitleCase(output),
    hsenses = factor(output, levels = senses)) %>%
  ggplot(aes(x=hsenses, fill=hsenses)) +
  geom_bar() +
  geom_text(aes(label=..count..),stat="count",position=position_nudge(), ,vjust=-
0.4, size=3, colour = "black") +

```

```

    geom_text(aes(label=ifelse(..count.. > 5, paste0(round(..count../sum(..count..) *
100,0),"%"),"")),stat="count",position = position_stack(vjust = 0.5), size=4,
color="white") +
  labs(x="", y="Frequency", title="Interpreting Devices (OUTPUT)", subtitle =
"Interactivity Analysis Framework") +
  theme(legend.position = "none") +
  scale_fill_brewer(direction=-1)

# SOCIAL INTERACTION
si <- c("STAGE_1", "STAGE_2", "STAGE_3", "STAGE_4", "STAGE_5")

apparatus %>%
  unnest(sociali) %>%
  select(sociali) %>%
  count(sociali) %>%
  mutate(percentage= n/sum(n)) %>%
  arrange(desc(n))

apparatus %>%
  unnest(sociali) %>%
  mutate(
    sociali = toupper(sociali),
    stages = factor(sociali, levels = si)) %>%
  ggplot(aes(x=stages, fill=stages)) +
  geom_bar() +
  geom_text(aes(label=..count..),stat="count",position=position_nudge(), vjust=-
0.4, size=3, colour = "black") +
  geom_text(aes(label=ifelse(..count.. > 5, paste0(round(..count../sum(..count..) *
100,0),"%"),"")),stat="count",position = position_stack(vjust = 0.5), size=4,
color="black") +
  labs(x="", y="Frequency", title="Social Interaction Stages", subtitle =
"Interactivity Analysis Framework") +
  theme(legend.position = "none") +
  scale_fill_brewer(direction=-1)

# MUSEOLOGY
mu <- c("TOUR","GAMIFICATION", "VIRTUAL", "PARTICIPATIVE", "SOCIAL")

apparatus %>%
  unnest(museum) %>%
  select(museum) %>%
  count(museum) %>%
  mutate(percentage= n/sum(n)) %>%
  arrange(desc(n))

```

```

apparatus %>%
  unnest(museum) %>%
  mutate(
    museum = toupper(museum),
    mus = factor(museum, levels = mu)) %>%
  ggplot(aes(x=mus, fill=mus)) +
  geom_bar() +
  geom_text(aes(label=..count..,stat="count",position=position_nudge(), ,vjust=-
0.4, size=3, colour = "black")) +
  geom_text(aes(label=ifelse(..count.. > 5, paste0(round(..count../sum(..count..) *
100,0),"%"),""),stat="count",position = position_stack(vjust = 0.5), size=4,
color="black")) +
  labs(x="", y="Frequency", title="Museum Taxonomy", subtitle = "Interactivity
Analysis Framework") +
  theme(legend.position = "none") +
  scale_fill_brewer(direction=-1)

# =====
# 3. Correlation
# =====

### MODES OF INTERACTIVITY
apparatus %>%
  unnest(medium) %>%
  ggplot(aes(x=medium)) +
  geom_bar(aes(fill=coherence)) +
  labs(x="Medium", y="Count", title="Modes of Interactivity") +
  # scale_colour_viridis_d(option = "plasma")
  scale_fill_brewer()

### Medium vs Coherence
apparatus %>%
  unnest(medium) %>%
  ggplot(aes(x=coherence, group=medium)) +
  geom_bar() +
  facet_grid(~medium) +
  labs(x="Medium", y="Percentage", title="Modes of Interactivity")

museomix %>%
  unnest(medium) %>%
  count(medium, coherence) %>%
  rename(Freq=n) %>%
  ggballonplot(x="medium", y="coherence", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +

```

```

    guides(size=FALSE) +
    scale_fill_viridis_c()

# Medium per Country
museomix %>%
  unnest(medium) %>%
  count(medium, country) %>%
  rename(Freq=n) %>%
  # spread(output, n, fill = 0) %>%
  ggballoonplot(x="medium", y="country", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

# Medium per Year
museomix %>%
  unnest(medium) %>%
  count(medium, year) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="medium", y="year", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

# Medium vs Social Interacting Scale
museomix %>%
  unnest(medium, .preserve = sociali) %>%
  unnest(sociali) %>%
  count(medium, sociali) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="medium", y="sociali", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Coherence vs Year
museomix %>%
  count(coherence, year) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="coherence", y="year", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Coherence vs Country

```

```

museomix %>%
  count(coherence, country) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="coherence", y="country", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### INPUT / OUTPUT
museomix %>%
  unnest(input, .preserve = output) %>%
  unnest(output) %>%
  ggplot(aes(x=input)) +
  geom_bar(aes(fill=output)) +
  labs(x="Input", y="Count", title="Input Output Correlation") +
  scale_fill_brewer(palette = "Spectral")

museomix %>%
  unnest(input, .preserve = output) %>%
  unnest(output) %>%
  count(input, output) %>%
  rename(Freq=n) %>%
  # spread(output, n, fill = 0) %>%
  ggballoonplot(x="input", y="output", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

museomix %>%
  unnest(medium, .preserve = c(input, output)) %>%
  unnest(input, .preserve = c(output)) %>%
  unnest(output) %>%
  count(input, output, medium) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="input", y="output", size = "Freq", fill = "Freq", ggtheme =
theme_light(), facet.by = "medium") +
  scale_fill_viridis_c() +
  guides(size = FALSE)

museomix %>%
  unnest(input, .preserve = c(output, sociali)) %>%
  unnest(output, .preserve = sociali) %>%
  unnest(sociali) %>%
  count(input, output, sociali) %>%
  rename(Freq=n) %>%

```

```

  ggballoonplot(x="input", y="output", size = "Freq", fill = "Freq", ggtheme =
theme_light(), facet.by = "sociali") +
  scale_fill_viridis_c() +
  # coord_flip() +
  guides(size = FALSE)

### MEDIUM, COHERENCE, SOCIAL_INTERACTIONS
museomix %>%
  unnest(medium, .preserve = c(input, output, sociali)) %>%
  unnest(input, .preserve = c(output, sociali)) %>%
  unnest(output, .preserve = sociali) %>%
  unnest(sociali) %>%
  count(medium, coherence, sociali) %>%
  ggballoonplot(x="medium", y="coherence", size = "n", fill = "n", ggtheme =
theme_light(), facet.by = "sociali") +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### SOCIAL INTERACTION SCALE

# Social Interactin Scale vs Year
museomix %>%
  unnest(sociali) %>%
  count(year, sociali) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="sociali", y="year", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

# SIS vs Country
# Social Interactin Scale vs Year
museomix %>%
  unnest(sociali) %>%
  count(country, sociali) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="sociali", y="country", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### MUSEOLOGY

### Museology vs Country

```

```

museomix %>%
  unnest(museum) %>%
  count(museum, country) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="museum", y="country", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Museology vs Year
museomix %>%
  unnest(museum) %>%
  count(museum, year) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="museum", y="year", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Museology vs Medium
museomix %>%
  unnest(museum, .preserve = medium) %>%
  unnest(medium) %>%
  count(museum, medium) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="museum", y="medium", size = "Freq", fill = "Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Museology vs Coherence
museomix %>%
  unnest(museum) %>%
  count(museum, coherence) %>%
  rename(Freq=n) %>%
  ggballoonplot(x="museum", y="coherence", size = "Freq", fill="Freq", ggtheme =
theme_light()) +
  scale_fill_viridis_c() +
  guides(size = FALSE)

### Museology vs Social Interaction Scale
museomix %>%
  unnest(museum, .preserve = c("sociali")) %>%
  unnest(sociali) %>%
  count(museum, sociali) %>%

```

```

rename(Freq=n) %>%
ggballoonplot(x="museum", y="sociali", size = "Freq", ggtheme = theme_bw()) +
# scale_fill_viridis_c() +
guides(size = FALSE)

# =====
# 4. Demography
# data source: https://drive.google.com/file/d/0B\_fKc58DIYkmaS1kMUNVSTh3Y3c/view
# =====

# 4.1 Female/Male Ratio
mf <- data.frame(group = c("Male", "Female"), value = c(141, 250))

mf <- mutate(mf,
  cumulative = cumsum(value),
  midpoint = cumulative - value / 2,
  percentage = round(value/sum(value) * 100,0),
  label = paste0(percentage, "%\n(", value, ")"))
head(mf)

ggplot(mf, aes(x="", y=value, fill=group))+
  geom_bar(width = 1, stat = "identity") +
  coord_polar("y", start=0) +
  geom_text(aes(x = 1, y = midpoint, label = label)) +
  theme_minimal() +
  scale_fill_brewer(palette = "Blues") +
  labs(x="", y="", fill="", title="Female / Male Ratio", subtitle = "2014 Museomix
Participants")

# 4.2 Age
age <- data.frame(
  group = c("<20", "20-29", "30-39", "40-49", "50-59", ">60"),
  value = c(3,146,124,75,23,8)
) # NA: 12

age %>%
  mutate(group2 = factor(group, levels = group),
    percentage = round(value/sum(value)*100,0))

age %>%
  mutate(group2 = factor(group, levels = group),
    percentage = round(value/sum(value)*100,0)) %>%
  ggplot(aes(x=group2, y=value, fill=group)) +
  geom_bar(width = 1, stat = "identity") +

```

```

    geom_text(aes(label=value),stat="identity",position=position_nudge(), ,vjust=-
0.4, size=3, colour = "black") +
    geom_text(aes(label=paste0(percentage,"%")),stat="identity",position
=
position_stack(vjust = 0.5), size=4, color="black") +
    labs(x="Age", y="Frequency", fill="", title="Age Groups", subtitle ="2014 Museomix
Participants") +
    theme(legend.position = "none") +
    scale_fill_brewer()

# 4.3 Education Level
edu <- data.frame(
  group = c("< High School", "Associate Diploma", "Bachelor", "Master", "PhD"),
  value = c(21,30,44,263,33)
)

edu %>%
  mutate(group2 = factor(group, levels = group),
         percentage = round(value/sum(value)*100,0)) %>%
  ggplot(aes(x=group2, y=value, fill=group)) +
  geom_bar(width = 1, stat = "identity") +
  geom_text(aes(label=value), position=position_nudge(), ,vjust=-0.4, size=3, colour
= "black") +
  geom_text(aes(label=paste0(percentage,"%")),stat="identity",position
=
position_stack(vjust = 0.5), size=4, color="black") +
  labs(x="", y="Frequency", fill="", title="Education Distribution", subtitle ="2014
Museomix Participants") +
  theme(legend.position = "none") +
  scale_fill_brewer()

# =====
# 5. EXPORT
# Export simplified dataset for Appendix 3 of the thesis
# =====
appendix3 <- apparatus %>%
  select(name, place, city,year) %>%
  arrange(year, city)
View(appendix3)

```

APPENDIX 3

LIST OF INTERACTIVE APPARATUSES

This list represents all interactive apparatuses analysed during the course of our work. They are all from one of the Museomix events, except for two additional apparatuses as mentioned in chapter 6.

#	Title	Museum	City	Year
1	Kaléidomix	Musée des Arts Décoratifs	Paris	2011
2	Visite en perspective	Musée des Arts Décoratifs	Paris	2011
3	La machine du Baron Münchhausen	Musée des Arts Décoratifs	Paris	2011
4	Opération Dragon	Musée des Arts Décoratifs	Paris	2011
5	Splendeur ou misère des courtisanes	Musée des Arts Décoratifs	Paris	2011
6	Rhinoceros détourné	Musée des Arts Décoratifs	Paris	2011
7	The place to seat	Musée des Arts Décoratifs	Paris	2011
8	La danse serpentine	Musée des Arts Décoratifs	Paris	2011
9	Meubles que cachez-vous ?	Musée des Arts Décoratifs	Paris	2011
10	Strat	Musée des Arts Décoratifs	Paris	2011
11	Savez-vous garder un secret ?	Musée des Arts Décoratifs	Paris	2011
12	Scriptomix	Musée Gallo-Romain	Lyon	2012
13	Six pieds sous terre	Musée Gallo-Romain	Lyon	2012
14	La visite dont vous êtes le Héros	Musée Gallo-Romain	Lyon	2012
15	Mare nostrum	Musée Gallo-Romain	Lyon	2012
16	Arrête ton char Benhur	Musée Gallo-Romain	Lyon	2012
17	Bruits de quartier	Musée Gallo-Romain	Lyon	2012
18	Storytelling	Musée Gallo-Romain	Lyon	2012
19	Mekanik'Antik	Musée Gallo-Romain	Lyon	2012
20	Fenêtre sur le passé	Musée Gallo-Romain	Lyon	2012
21	Lugdunum révèle-toi	Musée Gallo-Romain	Lyon	2012
22	Gens de l'Alpe: rejoignez la communauté	Musée Dauphinois	Grenoble	2013
23	Mur[murs]	Musée Dauphinois	Grenoble	2013
24	Le Musée dont je suis le héros !	Musée Dauphinois	Grenoble	2013
25	Lever les Yeux	Musée Dauphinois	Grenoble	2013
26	La machine à contes	Musée Dauphinois	Grenoble	2013
27	L'Homme Sauvage	Musée Dauphinois	Grenoble	2013
28	Les Dessous Menteurs	Musée Dauphinois	Grenoble	2013
29	Tout schuss	Musée Dauphinois	Grenoble	2013
30	Oh My Gallery!	Louvre-Lens	Lens	2013
31	Explora: mixe le Nord	Louvre-Lens	Lens	2013
32	murMur	Louvre-Lens	Lens	2013

33	La Jali	Louvre-Lens	Lens	2013
34	Le fil rouge de la Niobide	Louvre-Lens	Lens	2013
35	Blablamix	Louvre-Lens	Lens	2013
36	Rideau!	Château des Ducs de Bretagne - Musée d'histoire	Nantes	2013
37	Estu'AR	Château des Ducs de Bretagne - Musée d'histoire naturelle	Nantes	2013
38	On s'affiche!	Château des Ducs de Bretagne - Musée d'histoire naturelle	Nantes	2013
39	Crac Boum Château	Château des Ducs de Bretagne - Musée d'histoire de Nantes	Nantes	2013
40	Grattophone	Château des Ducs de Bretagne - Musée d'histoire	Nantes	2013
41	Verre le Rével!	Musée des Arts Décoratifs	Paris	2013
42	#neverstop	Musée des Arts Décoratifs	Paris	2013
43	Et surtout...	Musée des Arts Décoratifs	Paris	2013
44	Archi +	Musée des Arts Décoratifs	Paris	2013
45	Enquête aux Arts Décoratifs	Musée des Arts Décoratifs	Paris	2013
46	Icube	Musée des Arts Décoratifs	Paris	2013
47	Pimp my Room	Musée des Arts Décoratifs	Paris	2013
48	Nomades	Musée des Arts Décoratifs	Paris	2013
49	Palabrama	Musée des Arts Décoratifs	Paris	2013
50	Tire-toi une bûche! Assieds-toi dans l'Histoire	Musée de la Civilisation	Québec	2013
51	MUSÉES À IMAGES	Musée de la Civilisation	Québec	2013
52	Il était mille fois...	Musée de la Civilisation	Québec	2013
53	L'enfer	Musée de la Civilisation	Québec	2013
54	Café Inuit	Musée de la Civilisation	Québec	2013
55	ARTualité	Musée de la Civilisation	Québec	2013
56	L'art du secret	Musée de la Civilisation	Québec	2013
57	[Re]crée ton musée	Musée de la Civilisation	Québec	2013
58	Le Thermomix rescopé	Musée de la Civilisation	Québec	2013
59	Court-court-métrage	Musée de la Civilisation	Québec	2013
60	WOW Wonder of Water	Coalbrookdale Museum of Iron	Shropshire	2013
61	Iron Insight	Coalbrookdale Museum of Iron	Shropshire	2013
62	Ironbridge Next Top Model	Coalbrookdale Museum of Iron	Shropshire	2013
63	Superhero Visitors	Coalbrookdale Museum of Iron	Shropshire	2013
64	The Bold Furnace	Coalbrookdale Museum of Iron	Shropshire	2013
65	The Pot That Changed The World	Coalbrookdale Museum of Iron	Shropshire	2013
66	MuSeOtHeRaPy	Musée départemental Arles antique	Arles	2014
67	Aiôn'Snake	Musée départemental Arles antique	Arles	2014
68	L.O.C.O (Ligue opérationnelle contre l'oubli)	Musée départemental Arles antique	Arles	2014
69	Voyage en eaux troubles	Musée départemental Arles antique	Arles	2014
70	Suivez le fil	Musée départemental Arles antique	Arles	2014
71	Dépôt'ware	Musée départemental Arles antique	Arles	2014
72	Antik[en]Kit	Musée départemental Arles antique	Arles	2014

73	Costumix	Musée départemental Arles antique	Arles	2014
74	ENGauge	Silk Mill Museum	Derby	2014
75	Cooleurs	Musée d'art et d'histoire	Genève	2014
76	MAH Machine	Musée d'art et d'histoire	Genève	2014
77	Corps à corps	Musée d'art et d'histoire	Genève	2014
78	museochoix	Musée d'art et d'histoire	Genève	2014
79	Les insomniaques du musée	Musée d'art et d'histoire	Genève	2014
80	Alice et le Minotaure	Musée d'art et d'histoire	Genève	2014
81	Le Musée Secret	Musée d'Histoire Naturelle	Lille	2014
82	Vu d'ici	Musée d'Histoire Naturelle	Lille	2014
83	Evolumix	Musée d'Histoire Naturelle	Lille	2014
84	MIX'OS	Musée d'Histoire Naturelle	Lille	2014
85	The Dragonfly Horror Show	Musée d'Histoire Naturelle	Lille	2014
86	le VisitoMètre	Musée d'Histoire Naturelle	Lille	2014
87	Rock on the rocks	Museum d'Histoire Naturelle	Nantes	2014
88	L'Holo Fossile	Museum d'Histoire Naturelle	Nantes	2014
89	Enviromate	Museum d'Histoire Naturelle	Nantes	2014
90	Qui a peur de qui?	Museum d'Histoire Naturelle	Nantes	2014
91	Le Coquiphone	Museum d'Histoire Naturelle	Nantes	2014
92	OMOH SAPI3NS	Museum d'Histoire Naturelle	Nantes	2014
93	OiseauxMix !	Museum d'Histoire Naturelle	Nantes	2014
94	MuseoZoom	Musée d'Art et d'Industrie	Saint-Etienne	2014
95	La roue libre	Musée d'Art et d'Industrie	Saint-Etienne	2014
96	Muséocyclette	Musée d'Art et d'Industrie	Saint-Etienne	2014
97	La banque de fabrique de rubans	Musée d'Art et d'Industrie	Saint-Etienne	2014
98	Les Bruits qui Courent	Musée d'Art et d'Industrie	Saint-Etienne	2014
99	Le voyage des rubans	Musée d'Art et d'Industrie	Saint-Etienne	2014
100	Yan Character	Creative Macau	Macau	2017
101	Interactive Lamp	Macau Museum of Art	Macau	2019