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MUSEUM EXPERIENCE DESIGN BASED ON MULTI-SENSORY TRANSFORMATION APPROACH

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Abstract
Museums' main functions are to preserve pieces of art, transmit and share knowledge. They are proposing more and more solutions to address the access to information. In this paper, our main purpose is to improve visitors' learning experience and knowledge transfer in museums. First, we did theoretical background review about museum experience and multi-sensory experience. Then, we propose a new method based on “Multi-sensory transformation matrix”. Finally, we design the initial concept of a brand new multi-sensory solution that we plan to experiment with visitors in real museum environments.

Keywords: museum visitor experience, multisensory product experience, interaction design, user experience

1. Introduction
Museums play both a social and cultural role. Their main functions are to (i) preserve pieces of art and (ii) transmit and share knowledge (Hooper-Greenhill, 1994). The latter is made possible thanks to events and exhibitions putting visitors in front of pieces of art to appreciate them. Today, in most museums, visitors' experiences are limited to visual and passive relations with these pieces of art. Furthermore, many pieces of art are presented in protected environments creating a barrier -between the visitor and the piece of art- resulting in a restrained visitor experience.
In order to enrich visitors’ experience and develop interest and new audiences, museums are proposing more and more solutions to address the access to information and the ways to overcome limits to this access (Levent and Pascual-Leone, 2014). Amongst these, multi-sensory solutions seem to be the most promising for all categories of people, such as people with disabilities, elderly and young people and others. These multi-sensory solutions, which are intended to improve the interaction between all categories of visitors and pieces of art, are based on multi-sensory materials (Stoll Lillard, 2008).
Our study falls within the framework of museums experience design and visitors experience enrichment. It aims at understanding the current museum situation and developing new methods and solutions to enrich visitors’ experience. Our main purpose is to improve learning experience and knowledge transfer in museums.
In pursuit of these aims, we set up the following approach -presented in this paper-:

1. Theoretical background review about museum experience and multi-sensory experience
2. A new method based on “Multi-sensory transformation matrix” allowing designers to come up with novel multi-sensory solutions enriching visitors’ experience
3. Finally, a brand new multi-sensory solution

2. State of the art

The responsibilities of the world of museums thus far exceed the scope of the traditional mission of conservation and research. Today, the museum is a producer of aesthetic emotion and an intercultural mediator. And tomorrow, even more, its plural vocation will be decisive in contributing to the dialogue between cultures, to civic education and to living together (Eidelman et al., 2017). People come to museums carrying with them the rest of their lives, their own reasons for visiting and their specific prior experience (Hooper-Greenhill, 1994). In the definition of the Museum Experience Model (Falk and Dierking, 2013), as shown in Figure 1, the museum visitor's experience results from the overlapping of the physical context, the social context, and the personal context. The standard model suggests that each visitor's experience is different. Each visitor (i) brings his own personal and social contexts, (ii) is differently affected by the physical context, and (iii) makes different choices like which aspect of that context he wants to focus on.

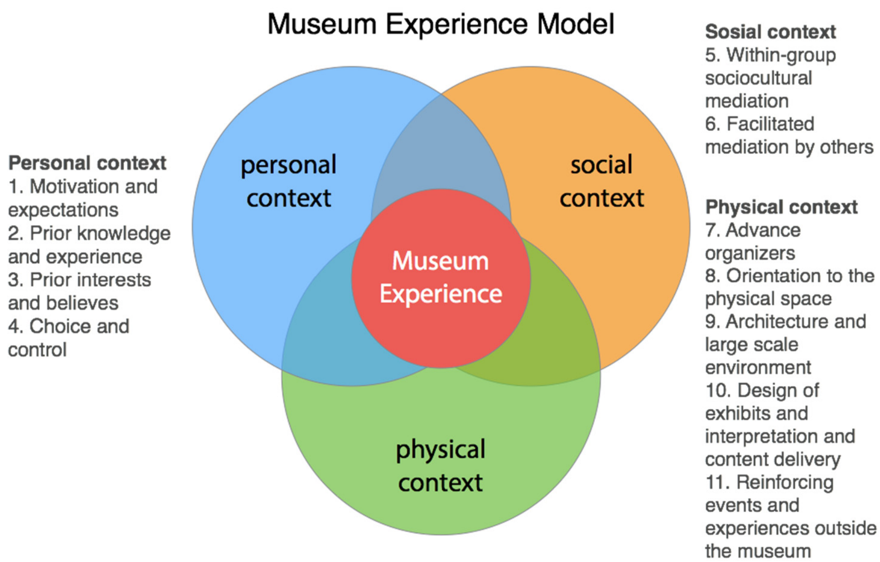

Figure 1. The Museum Experience Model (Falk and Dierking, 2013)

Museum visitor's experience is also defined as "a learning experience and knowledge transfer". Therefore, to improve visitor's experience in museums, one has to focus on visitors' learning experience and knowledge transfer.

Many scientists and researchers have dealt with learning experiences and knowledge transfer development using multi-sensory learning technics. Multi-sensory learning is the idea that learning is experienced through all the senses to help in reinforcing memory (Stoll Lillard, 2008). From the earliest teaching guides (Montessori, 1912), educators have embraced a range of multi-sensory techniques to make learning richer and more motivating for learners. The term refers to any learning activity that combines two or more sensory strategies to take in or express information. Research related to multi-sensory learning shows that when learners have more senses to connect new information to, they could remember things better after their experience (Shams and Seitz, 2008). Multi-sensory stimulation is also effective and appropriate for people with disabilities (Baker et al., 2001). However, the benefit of involving more than one sense during learning experience should not be limited to people with disabilities. A study that analyzed the long-term memories of museum visitors shows that museum visitors' identities, motivations and learning are inextricably intertwined (Falk, 2010). Museum visitor's experience is similar to a learning experience. Based on this, museums are able to use multi-sensory learning approach to offer the appropriate information to all categories of visitors. They are developing more and more multi-sensory solutions involving the five senses.

In our background review, we are focusing on two areas and existing devices helping to improve interaction between a visitor and a piece of art. Figure 2 shows two primary domains, (i) Museum experience (colored in green) and (ii) Multi-sensory experience (colored in orange), and 7 crossing fields -colored in white- connected to multi-sensory research topics which are: Museum guide (3.1), Multi-sensory learning (3.2), Multi-sensory materials (3.3), Interactive arts (3.4), Musical Instruments (3.5), Technologies for marketing (3.6), Technologies for a peculiar use (3.7)

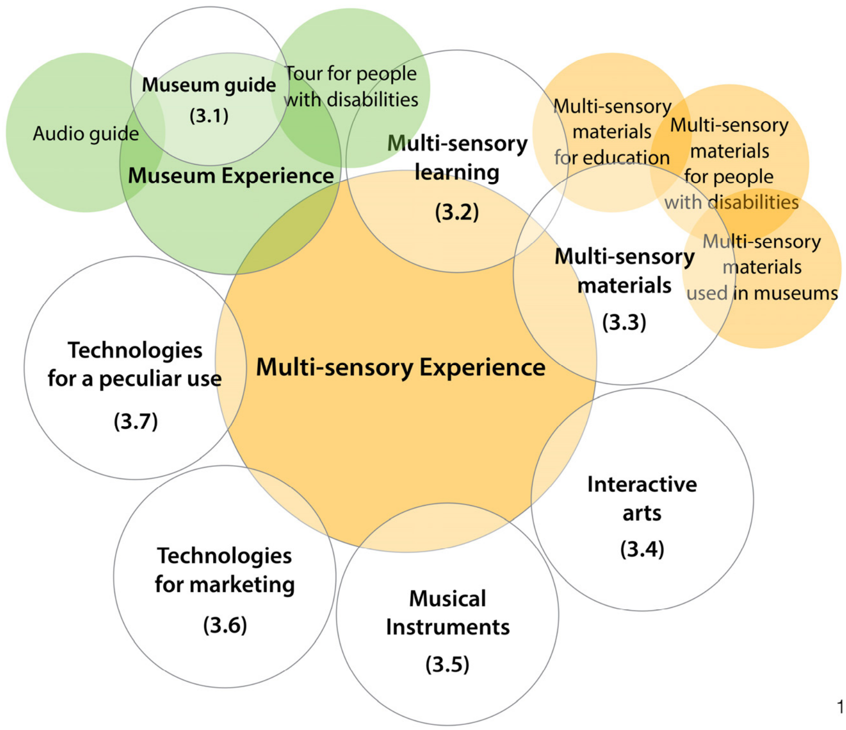

Figure 2. Areas of our background review

In order to make sure that our research includes the above mentioned research and technology, the following Table 1 summarizes all previously mentioned state of the art in terms of scope, and how to be applied to this project.

This table shows how each topic is applied to our research project: to (i) understand museum experience and issues for various categories of visitors, to (ii) understand benefits of multi-sensory solutions and to (iii) know latest technologies and research topics about multi-sensory solutions.

In many situations, people want information about objects in their physical environment. Visitors in museums often want to learn more about artworks. They typically obtain such information from paper guidebooks or electronic guidebooks. In the section (3.1), we gathered examples of guide devices commonly used in museums and tours to appreciate art works. There are several papers related to classification and design approaches of existing electronic guidebooks (Aoki and Woodruff, 2000; Albertini et al., 2005; Damala, 2009). In the section (3.2) and (3.3), we provide information about learning methods using multi-sensory stimulation. As people walk in museums, they want to learn more about art objects. Several papers demonstrate the effectiveness of multi-sensory stimulation during learning experience for better understanding (Kaczmarek, 2010; 3DPhotoWorks, 2015; Ucar, 2015; Logsdon, 2017).

In recent years, daily life involves constant multisensory stimulation and many multi-sensory solutions are used everywhere with latest technologies such as electronic musical instruments (Takeuchi, 1996), interactive art which is a type of art involving audiences into the artwork (Yasuaki Kakehi Laboratory, 2009; TASKO.inc, 2015; TATE, 2017) and technologies for marketing (Taste and Aroma Strategic Research Institute, 2012; Kubota, 2016). There are review meaningful themes to consider museum experience design. However, still few studies gather these themes at the same time as a holistic one for museum experience design. That is to say, the expected benefits of the state of the art are: to use advanced multi-sensory solutions, holistic and seamless museum experience design and multi-sensory experience. And it is hoped that the attempt of this study is not far to take into practice in the real world.

In our study, in order to improve visitor's experience, we focus on the physical context and particularly on the parameter "Design of exhibits, interpretation and context delivery".

Table 1. State of the art in terms of scope and project application

Section	State of the art	Reference	Scope	Project application
3.1	Audio guide	(Aoki and Woodruff, 2000) (Albertini et al., 2005) (Damala, 2009) (Orpheo, 2017)	MVE	Understanding museum experience and issues from visitor in museums
	Tour for people with disabilities	(The Museum of Modern Art, 2017)	MVE/ MSE	Understanding museum experience and issues from visitor in museums
3.2	Multi-sensory learning	(Stoll Lillard, 2008)	MSE	Understanding benefits of multi-sensory learning
3.3	Multi-sensory materials for education	(Logsdon, 2017)	MSE	Understanding educational benefits of multi-sensory materials
	Multi-sensory materials for people with disabilities	(Kaczmarek, 2010) (3DPhotoWorks, 2015)	MSE	Understanding multi-sensory solutions from people with disabilities
	Multi-sensory materials used in museums	(Ucar, 2015)	MVE/ MSE	Understanding multi-sensory solutions from visitor in museums
3.4	Interactive arts	(Yasuaki Kakehi Laboratory, 2009) (TASKO.inc, 2015) (TATE, 2017)	MSE	Latest technology and research topic about multi-sensory solutions
3.5	Musical Instruments	(Takeuchi, 1996)	MSE	Latest technology and research topic about multi-sensory solutions
3.6	Technologies for marketing	(Taste and Aroma Strategic Research Institute, 2012) (Kubota, 2016)	MSE	Latest technology and research topic about multi-sensory solutions
3.7	Technologies for a peculiar use	(Grant, 2009) (Bau et al., 2010) (Jagielo, 2014) (Rouzic, 2017)	MSE/ MVE	Latest technology and research topic about multi-sensory solutions

MVE: Museum visitor experience, MSE: Multi-sensory experience

3. Multi-sensory transformation approach

3.1. Definition

After the synthesis of the state of the art, we decided to organize all multi-sensory solutions using the Multi-sensory transformation approach.
A general design process has a 'divergent thinking' step where a number of possible ideas are proposed. In this step, a structured brainstorming takes place to identify opportunities and to explore new concepts (Design Council, 2015). New ideas are developed, tested and refined iteratively a number of times and weak ideas are dropped.
Multi-sensory transformation approach, which is a method using a 'Multi-sensory transformation matrix', aims at providing information about existing multi-sensory solutions. The 'Multi-sensory transformation matrix' is an effective tool helping divergent thinking. As shown in Figure 3, this matrix places the five human senses on the vertical and horizontal lines. Each cell of it corresponds to one or

several multi-sensory solutions. This matrix offers an exhaustive classification of multi-sensory solutions and could be used as follows: the classified solution in the cell allows the transformation of the sense of the horizontal line into the sense of the vertical line.

3.2. Classification

We classify multi-sensory solutions using the proposed matrix. For example: The audio-guide solution allows the transformation of visual sense into auditory sense. Also, we classify elements of the matrix into three cases as follows:

- Case 1 'Multi-sensory solutions currently used in museums', solutions that could be improved and used in other museums.
- Case 2 'Solutions not used in museums', solutions that could be adapted to museum usage.
- Case 3 'No identified solutions'; There is a possibility to come up with novel solutions.

An example of multi-sensory solutions is the program called 'Touch tour' developed by the Museum of Modern Art (MoMA) in USA. 'Touch tour' was designed for people with visual disabilities allowing them to hear art explanation while directly touching sculptures in museum (The Museum of Modern Art, 2017). This 'Touch tour' is classified in the Multi-sensory transformation matrix as a solution allowing to use haptic sense instead of visual sense to appreciate a piece of art. Audio-guide devices, commonly used in most museums, are typical examples of transforming visual sense into auditory sense (Orpheo, 2017). 'Tesla Touch' is a device built to enhance touch interfaces with tactile sensations. 'Tesla Touch' transforms visual sense into haptic sense using electrostatic vibration (Bau et al., 2010). 'Touch the sound' is a new attempt to feel sounds thanks to different senses. By using a 3D printer, an object representing a given recorded sound is printed. Visitors could literally touch that sound (Jagielo, 2014). Based on our research, these devices have never been used in any museum and could be useful to enrich museums visits.

3.3. Analysis

Our 'Multi-sensory transformation matrix' (i) classifies existing solutions and (ii) highlights cases where there is no identified solution.

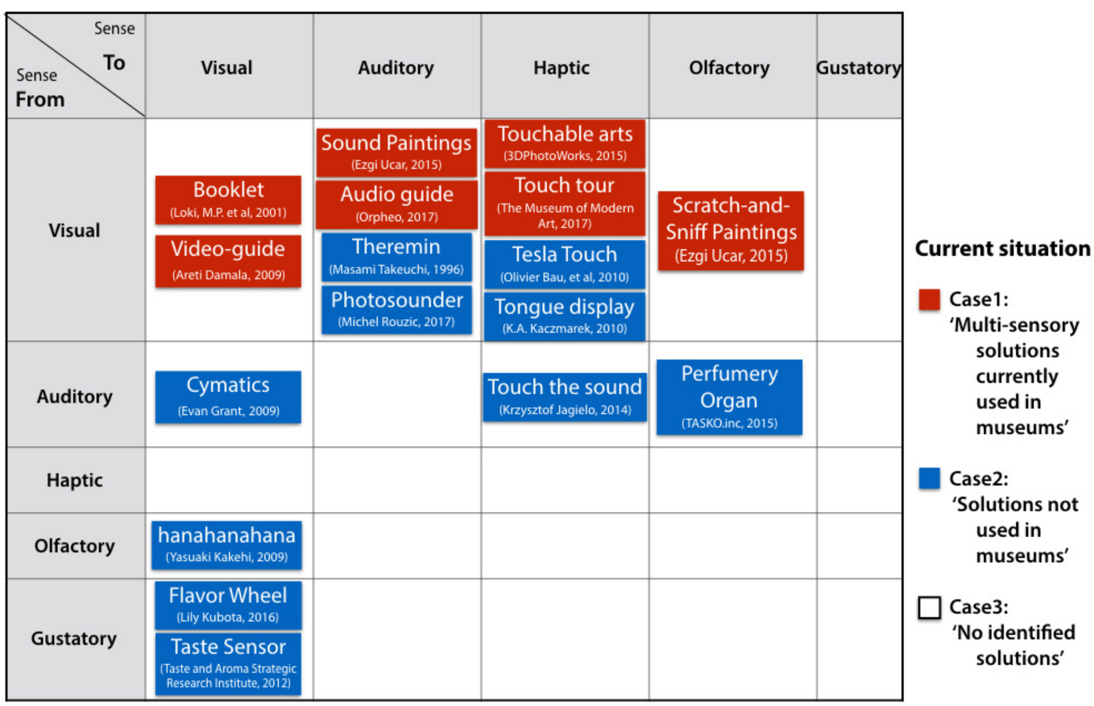

Figure 3. Classified solutions on the Multi-sensory transformation matrix

As a result of the current analysis, we can notice several boxes where there is no multi-sensory transformation solution. There are many empty boxes in the transformation from haptic sense into gustatory sense. And transformation from olfactory and gustatory sense are also less than other cases. It highlights a new solution corresponding to an empty box in the matrix, classified as case 3. Solution of multi-sensory transformation from haptic does not exist. From this knowledge, we draw our inspiration from the transformation from haptic sense to make a new multi-sensory solution for museum experience design.

From haptic sense, (i) there is a possibility in transforming into visual sense, however visitors already use their visual sense to appreciate a piece of art. Regarding olfactory sense, (ii) even if a scent is able to be changed following a shape, humans' olfactory receptors cannot cope with such change. The ability of human isn't enough to smell the changing scent every moment according to the morphology of the shape. (iii) For gustatory sense, it is also difficult for humans to respond to multiple taste changing in a short moment. Also, taste is a chemical reaction so it is difficult to create. On the other hand, both the auditory sense and the haptic sense are the senses of detecting vibration. (iv) Regarding auditory sense, the air vibration is amplified by our eardrum, the frequency of vibration is broken down and transmitted to our brain. (v) Haptic sense is the sense recognized by replacing the shape of the object converting it into vibration or pressure by touching it. Haptic is a touch sensation, and auditory is an indirect touch sensation created by touching the air. Vibrations are the common link between touch and auditory senses. Based on this statement, haptic and auditory sensations have been converted into electric signals. In addition, visitors are not allowed to touch the art work, it is a strict constraint in a museum in most cases. Then, we considered that visitors' learning efficiency and knowledge transfer would be improved by incorporating vibrations into the experience of the visitor.

Based on this notion, we came up with a design concept named "Remote touch". In this study, we develop this new multi-sensory solution.

4. "Remote touch - a multi-sensory solution"

4.1. General design concept

Visitors typically obtain information from guidebooks, which tend to limit the visitor to a relatively linear experience. Guidebooks cannot feasibly contain all information about all objects. People often have trouble looking up information about specific object or exhibit (Aoki and Woodruff, 2000). Visual perception is suitable for comprehensive recognition because people can grasp the whole at once. However, it is difficult to grasp the details by visual sense from a remote position. On the other hand, haptic perception is a way to grasp the shape by moving our hands gradually touching the object from the detail. Haptic experiences allow visitors to notice a slight change in objects that they do not usually notice. According to these notions, we defined "Remote touch" device design criteria based on learning effects by experience of touching:

1. Real-time haptic feedback can be obtained
2. Creating interactions between visitors and the piece of art
3. Provide a novel awareness of a piece of art by remote haptic experience
4. Learning effects by touching real art objects instead of touching the figures imitating art objects

4.2. Perspective design

This device is a wearable shape that fits on the hand of a visitor. The body of the device including a microcomputer is worn like a wrist-watch and small finger sacks including actuators, distance sensor and a vibration motor fit on all fingertips. When the main body is powered on, a distance sensor measures the distance and a vibration motor creates vibration according to the distance to an object. By feeling this vibration, visitors feel as if they are touching an object.

With this wearable device, visitors receive vibrations according to the movement of all fingers so that they can feel a more refined sensation on fingertips than when they hold a small handy device. Humans detect various deformations of the skin by tactile receptors. After being processed in the spinal cord and brain, this detected information is used for various processing under conscious and unconscious state.

The reason why we arranged the vibrators on fingertips is that tactile receptors are located on the opposite side of nails on fingertips.
The main functions of this device are listed below:

1. A distance sensor on the fingertip measures the distance to the art object.
2. A vibration motor provides vibration feedback according to the distance from art object, haptic information along the shape.

5. Discussion

As we introduced in the first part of this paper, all objects and environments that surround us generate multi-sensory experience. We applied multi-sensory solutions to the framework of museum experience and we conducted a theoretical background review on important fields related to museum's device design. We succeeded in comprehensively examining existing current multi-sensory solutions that spanned various fields. Thanks to this review, we came up with our approach to analyze all these solutions into human five senses.
Our approach could be applied in the process of divergent thinking of museum experience design. Thanks to the Multi-sensory transformation matrix, we enabled an exhaustive classification of all multi-sensory solutions found in the background review introduced at the beginning of this paper.
In this study, we designed the initial concept and the perspective design born from our approach. The remote touch device was discovered as a solution that could improve learning experience and knowledge transfer mostly as a result of analyzing existing current multi-sensory solutions. Furthermore, this idea came from a persona assuming one kind of museum visitor (single, young adult, willing an experience of easiness and fun while visiting a museum). Museum visitors are different and a persona can be imagined differently: children, elderly people and foreigners. If we implement different persona, even if using the same concept of a transformation from haptic sense, another design of a device could be generated.
This device is under development. Further works on this primary concept will proceed from prototyping to user test protocols. In order to confirm that this proposal improves the learning experience and knowledge transfer in museums, it is mandatory to experiment on the field with visitors in a real museum to stress our approach and our hypothesis.

6. Conclusion

In conclusion of this research we can state that the primary goals have been achieved. We established a theoretical background review about museum experience and multi-sensory experience. Then we proposed a new method based on a framework called "Multi-sensory transformation matrix". Thanks to the proposed matrix, we can discover novel multi-sensory solutions to improve visitor's learning experience and knowledge transfer in museums. Finally, our new mediation approach will generate a brand-new solution, helping designer to develop a multi-sensory solution for enriching museum visitor experience.

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