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Article

Smart Experience in Fashion Design through Smart Materials Systems: Outlining a New Creative landscape Emerging Practices between Design Aesthetics

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Abstract: During the last decade, smart materials have increasingly impacted on several niches, among which that of one-off/limited edition experimental fashion. Thanks to their performativity, due to the implementation of *Smart Materials Systems*, they have reached indeed catwalks as well as museums and galleries. As boundaries between what-is-art and what traditionally was not supposed to be art are now turning into osmotic membranes, zooming on how smart materials are highly contributing to outline the new creative landscape can provide with interesting and compelling issues. Introducing three different areas of experimental fashion, named *Multi-sensory dresses*, *Empathic dresses*, and *Bio-smart dresses and accessories*, respectively covering the world of in-Lab experiments and design collaborations in relation to the application of advanced smart materials systems, the article discuss some of the implications in term of Design Thinking and Design Aesthetics.

Keywords: Smart Material Systems; Augmented Material; Creative practices; Fashion Design; Smart Experience; Smart Aesthetics; Technology.

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1. Introduction

During the last decade, new advanced media, and *augmented materials* (Razzeque et al. 2013; Ferrara 2017 p. 176) jointly with digital technologies, have increasingly impacted on several niches, among which that of one-off/limited edition experimental fashion.

The advanced materials we refer to in this article are mainly generally named *Smart Materials,* an expression that today includes different types and categories of materials and *material systems* able to mediate between analogic and digital worlds. Generally defined as "highly engineered materials that respond intelligently to their environment" (Addington and Scodek 2005 p. 9), as well as sensible and interactive (Cardillo and Ferrara 2008), smart materials are often embedded in conventional materials and applied in system with microelectronic components, in order to obtain *Smart Materials System*, also named *ICS_Material*, i.e *Interactive, Connected and Smart Materials* (Ferrara et al. 2018), in a design vision of advanced performance objects system featured by augmented behaviors and *smart user experience* (Bengisu and Ferrara 2018 p. 84). So material surfaces, as fabrics, can become sensitive and responsiveness (with visual, kinetic, and acoustic response) to external stimuli, monitor complex behavior in daily life, acquire an active and autonomous behavior with no need of human intervention (Bengisu and Ferrara 2013 p. 24), and ability to transfer and receive information. New smart surfaces are able to transform the artifacts from static to dynamic entities.

Last but not least, among the smart materials systems, we refer also to *Bio-smart Materials* (Lucibello et al. 2018), material systems in which the *artificial intelligence* and *intelligence in nature* are interconnected to complement one to another. This is to mean that the bio-smart materials have an intelligent behavior in a biological sense, or they yield the intelligence of nature integrating it with artificial intelligence systems

As already stated in the middle eighties, advanced materials are characterized more by their performance rather than their functionality (Manzini 1986), and specifically smart materials systems performance is no doubt a powerful stimulus for creative practices, promising much more in relation to current paradigms based on communication, interaction, sustainability and human experience (Bengisu and Ferrara 2018).

Nowadays all these new tools, together with new technologies like 3D printing, and new design approaches, like interaction, algorithmic and biomimetic design, have started to be used in creative practice both as catalysts of the design process, allowing artists and designer to interact directly with the technological reality, and as active agent of an extraordinary field of experimentation on expressive languages, sophisticated functionality, user perceptive and emotional involvement. Thanks to their performances, the application of smart materials systems has been the focus of many researches and experimentations of fashion innovation, were they paves the way to the enhancement of programmable and interactive dresses, accessories and shoes, contributing to their implementation as wearable technologies. So they have reached indeed catwalks as well as museums and galleries. The amount of art & fashion design public presentation of "experiential prototyping" (Buchenan and Suri 2000) that have already captured a big audience proposing a highly experiential involvement, are clear indications of the increasing interest among arts, design and fashion communities toward the appropriation of augmented materials toward application on products and a new emerging Design Aesthetics. In some cases these experimental prototypes are close to reaching the market.

2. Method

Assuming that in the contemporary creative practices environment through performance, fashion designers have adopted a role of *designer-as-artist* shaping a phenomenon with plenty of symptoms in different creative activities niches, we will analyzes experimental one-off/limited edition fashion mainly related with *science-design* (Duggan 2001). In this field of creative investigations deeply involved in science and active research practices, the use of technological and scientific advances contribute breaks the boundaries of traditional art-making, recognizing the physical process as the actual work (Rush 1999 p. 48). Science-designers and Material-designer emphasize the function and performances of materials and their artifacts. The material creation and construction of prototype dictate the performance. This is evident in their processes, and in the communication of their work that utilize videos that incorporate transformation as a means of revealing the experimentation behind the work. Science-fashion-designer utilizes their fashion shows as art performance extending the customer's involvement in their creative process.

As boundaries between what-is-art and what traditionally was not supposed to be art are now turning into osmotic membranes, zooming on how *Smart Material System*, are highly contributing to outline the new creative landscape can provide with interesting and compelling issues. All worthy to be further analyzed, not just in terms of Art Theory, but through the lens of *Design Thinking* and *Design Aesthetics*.

In order to highlight the implementation of emerging technology and smart material system on experimental fashion design, now articulated in several niches and sub-niches, we introduce three different areas of to highly performing experimental dresses, with relative promising case-studies, respectively covering the world-wide of in-Lab experiments and design collaborations. We will then questioning the impact caused by smart materials and then smart wearing objects, and highlight some of the communicational and the relational issues potentially generated, partially referring also to *Design Aesthetics*.

More than ever, questioning performances and involvements discloses then as the core of a contemporary creative approach, where unedited inspirational and pursued completions are encouraging new implementations, generating interesting and extremely useful outcomes. Indeed,

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with all the material potential currently available, envisioning what will be next in terms of smartness and yet unedited performances and applications is what also pushes further creativity and contemporary *Design Thinking*.

3. Multi-sensory dresses

What stated above in relation to the increasing opportunities, pursued by a new generation of artists, technologists, and designers, aiming to establish profitable collaborations with digital technology and science, is perfectly mirrored by what recently occurred at Royal college of Art in London, while developing a highly innovative dress concept, in partnership with algorithm design, sound designer and technologists.

WIM (Figure 1) is the project conceived by Jun Kamei, Kate McCambridge and Jacob Boast, in collaboration with Duncan Carter. WIM investigates the communication of movement and was designed to delivering haptic sensations across the body and built on the fields of neuroplasticity and haptic researches used to promote motor learning and rehabilitation. The developed prototype is a haptic dress. The design embed in the fabric lines of electric-driven artificial muscle made of polymer (Electro-Active Polymer). EAPs are smart material with the peculiarity of the *Materials that Move* (Bengisu and Ferrara 2018), as well as artificial digital technologies that delivers sensory stimulation to the joints and skin of a user body communicating information about the sequence and nature of movements. So WIM can receive data and instructions about the body's implicit movement in order to activate the expansion, contraction and vibration of the artificial muscles.

Working with dancers and performers to inform the placing and integration of this technology, the result was a live choreography system performed at Victoria and Albert Museum, London, during the Reveal Festival, hosted in collaboration with Boiler Room. In that result was fundamental the collaboration with Abnormal, a studio specialized in bringing digital craft to technology enabled contemporary art. The studio collaborated with the designers to materialise the performance of WIM with a new haptic-based language developed to assist with directing and choreographing movement. In order to assist in the communication of WIM's functionality from the stage to the audience, Abnormal developed a generative and immersive soundscape showing the interplay between dancer and choreographer. The soundscape takes the form of an electronic, ambient, surround-sound piece that is contorted and distorted by messages sent by a choreographer to the dancer's garment. The algorithmic approach to sound design enables the soundscape to respond to the performance in real time and to both adapt to input from the choreographer and actively affect the dancers movement. It enables WIM to not only facilitate a real-time conversation between the dancer and the choreographer, but to also complete that feedback loop by adding the soundscape as an actor.

WIM win the Haptic design Award 2017 in Tokio. Potential applications of WIM include physical rehabilitation, athletic training and sharing movement with others.

Recently, even the company giant Tesla has shown interest in the implementation of haptic technologies in a garment. Tesla proposes a concept of a suit for engagement in virtual reality play games or experiences that enhance the visual experience of VR headsets. *Teslasuit* apply on the fabric a neuromuscular electrical stimulation system, inspired to rehabilitation and athletic training techniques in physical therapy, in order to provide an electro-tactile haptic feedback distributed in the whole body. This system made of 46 thermo-controlled haptic sensors located on the front and back of body, stimulates the wearing nerves directly with electricity. The stimulations are very similar to the body's own native language and provide the sensory experience giving you the ability to touch and feel objects inside the VR. The range of electrical stimulation can vary from a gentle breeze to the simulation of the sensorial experience of an impact, not giving you the full on bud experience. Motion capture sensors and a library chock full of programmed animations allow the system to simulate a wide range of haptic impacts, like the subtle patter of raindrops against the skin, the cold gust of wind, the warmth of a dragon's flame, or the hit of a sword across the body.

Teslasuit is only one of the last stages of the wearable devices development for VR phenomenology, that succeed since the early 90s. But while before these products remained in a very

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market niche separated from the rest of the big market production, today the technological miniaturization, the democratization of technology, new printing technic for microelectronics with a more low cost, are promoting the cross-disciplinary experimentation. Experimental fashion, health-care wearable technologies, and VR devices apply these new technologies to differentiated utilities, which can go precisely from the application to dance to motor rehabilitation.

Figure 1. WIM haptic dress by J. Kamei, K. McCambridge and J. Boast. Courtesy J. Kamei

4. Empathic Dresses

Already in 2015, Behnaz Farahi working in the intersection of fashion and interaction design, explored through her project *Caress of the Gaze* the potential of emerging technologies and interactive systems and their relationship to the human body (Farahi 2015 2016). She created indeed a garment as a sort of primary interface, enabling the person wearing it to experience one of the main aspects of human interaction: people's gaze. The project was essentially based on eye-gaze tracking technology, where the garment itself relies on a smart system that uses a facial tracking camera detecting the orientation of the gaze, a microcontroller, SMA wires connected with a 3D printed mesh of PLA which give shape to the garment, and eight SMAs as the actuators (Bengisu and Ferrara, 2018). This miniaturised complex materials system allows the garment to move in response to the gaze of other people.

In 2017 the same designer released another wearable concept called *Opale*, a custom-made fashion item, integrating soft robotics and again facial tracking technology (Figure 2). It was launched as a new step forward, relying on the same technology already tested and implemented on *Caress of the Gaze*. Inspired by animal fur, the outfit is composed of a forest of optic fibers embedded in a silicon layer, whose fur bristles when under threat, or which purrs if eventually stroked (Farahi 2017). It is also provided with a camera able to detect a certain range of facial expressions, and it incorporates also an interactive pneumatic system responding accordingly. For example, the garment can respond to the manifestation of feelings like "anger" by compulsive or agitated movements, but it can also react to surprise by bristling, hence influencing social interaction.

Analyzing the design choices for *Opale* and *Caress of the Gaze*, we can see the interest that the human and / or animal behavior plays in Behnaz Farahi as an element of inspiration, in particular the involuntary skin responses such as chills or defence mechanisms. In fact, as Farahi (2016) explains, the skin of living beings, humans, animals or even vegetables, is constantly in motion, expanding, contracting, and changing its shape based on various internal/ external stimuli. It applies human behaviours to outfits, responding to various social issues such as intimacy, privacy, gender, and identity.

Compared to *Caress of the Gaze*, *Opale* project goes beyond the interest compared to project 1, 2 it goes beyond the interest in the behavior of human skin and animal fur. *Opale* is inspired by the facial-feedback hypothesis, which according to empirical research presides over the social understanding of emotions (Caruana and Gallese, 2011). According to research in experimental psychology, the incarnation of emotion through facial expression and posture affects the way in which

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emotional information is processed (Niedenthal 2014). Although this research has been a scandal in psychology, it is influencing the projects of designers, who are interested in influencing human emotions with their research like Behanaz Farahi. In fact, the intelligent dress *Opale* reproduces the "mirror mechanism for emotions". If you feel a certain emotion consists in the re-reading, at the cerebral level, of your body feed-back, the observation of the emotion of others, expressed in some particular gesture, influences the perceived emotional experience, and personal judgment. Thus by observing the expression of the emotions of others we connect directly with their meaning, reflecting the emotional behavior of others with our bodily expressions.

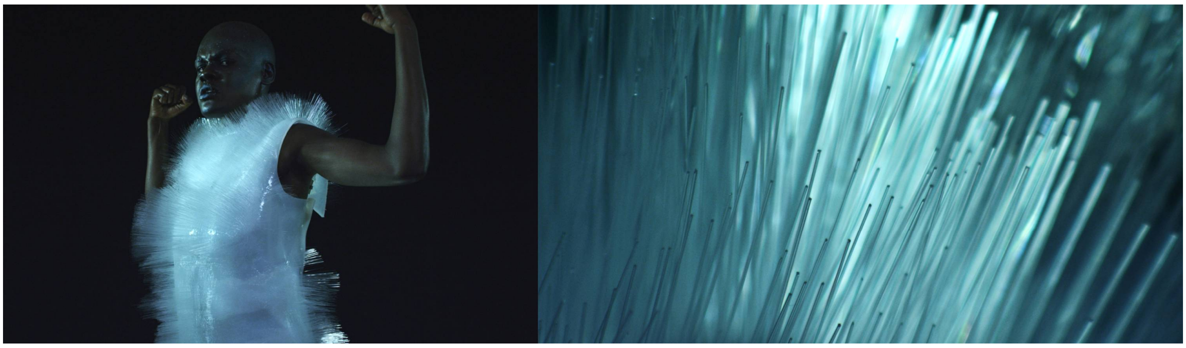

Fig. 2 Opale, emphatic dress by B. Farahi.

5. Bio-smart dresses and accessories

Another emergent creative niche, growing thanks the emergence of bio-smart fashion and design-biology integration, come full to light in 2015 with *bioLogic*, the research team leading by prof. Hiroshi Ishi in MIT's Tangible Media Group Lab, born from the collaboration among MIT Media Lab, MIT Chemical Engineering Department, and Royal College of Art (MIT 2018). This interdisciplinary team composed of designers, scientists and engineers created a completely new form of performance textile embedding alive actuators and sensors, the bacteria. The humidity-sensitive *Bacillus Subtilis Natto* was studied in its ability to the expansion and contraction in environment with atmospheric moisture. This natural phenomenon observed in a bio lab, was analyzed in its potentiality for functional use in dynamic fabric. Then, the team explored how bacterial properties can be applied to fabric and formed into living interfaces between body and environment. The animate *Natto* cells where assembled with a micron-resolution custom bio-printing system and cell-infused on a fabric in order to create a responsive material able to ventilate the skin of an athlete or a dancer, reacting to body heat and sweat. As fabric in a suit reacts to perspiration, tiny vents over bodily heat zones open and close allowing for rapid cooling.

In fall 2015, thanks to the collaboration with New Balance, interested to creating sportswear that regulates athletes' body temperatures, thereby enhancing performance, the *bioLogic* suits featured in a live ballet performance (Figure 3).

More recently, MIT Media Lab has used the same approach while developing a highly innovative shoe concept in partnership with athletic sportswear company Puma. Outwear designers applied indeed a brand new available technology to give shape to a next pair of performing sport shoes endowed with *Deep Learning Insoles*, powered by Biorealize studio. Briefly describing the technology itself, it seems of interest to remind that Deep Learning Insoles are silicone based disposable inlays containing microbial cultures, able to monitor biochemical vitals that normally change during running or workout. Since the very early stage of dissemination, also in terms of marketing, just as reported by the launching campaign, the role of bacteria was made quite clear and loud stating that "Microbial layer is composed of mini cavities that are filled with bacteria and media that are specialized in sensing different compounds present in sweat". Bacteria then respond to what they sense with specific chemicals causing a pH and a conductivity change in the sole itself, which gets recorded by a network of electrical circuits, connected to microcontrollers positioned in the

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third layer. Invisible living organisms are about then to dramatically change the very essence of workout and endurance routine and such a new step in bridging science and design is being broadly communicated also to potential mass consumers. Biology has always played a big role in all the various aspect of our life, but in such a specific case it is also contributing to extend the quality of living organisms also to something that, instead of being "animated" by software, or being programmed in advanced, contains a form of primitive life just within its own structure.

Looking at others experimental experiences in fashion design, like the synthetic biology by Carol Collet (Biolace), the creation of fashion and objects with biological materials is becoming one of the most promising research and development lines of the contemporary times, able to bring manufacturing back into play and reconcile it with the principles of nature, its models of sustainability and the peculiarities of different territorial contexts. Manufacturing processes and products innovation will have to use less and less irreversible chemical processes, but it will be able to use bacteria that will produce materials to create innovative clothing and accessories, investing on the sustainable principles as well as AI intelligence in the digital revolution and manufacturing 4.0 framework.

Fig. 3. *BioLogic*, by MIT Tangible Media Group Lab.

6. Discussion

Looking at the three different areas of experimental research presented in the previous paragraphs through selected cases deeply involved in active research practices, allows us to make some consideration on the evolution of performance wearable objects.

Before exploring the impact caused by smart materials systems, which so drastically differ from the conventional ones, it seems relevant to drive firstly the attention on the expansions and new peculiarities of the active creative practices environment associated with experimental fashion, where a strong convergence of different disciplines and approaches are taking place. The selected case studies, whether they are based in art or interaction design, show the emergence of interdisciplinary synergies, also with the involvement of disciplines such as neuroscience, or biology, that in a not so far past are considered not to be associated with clothes, not at all. Today creative research defines a complex territory of cross-disciplinary collaboration that characterizes the increasingly thin line between art, fashion design, and science. Artists and designers work together with technologists, biotechnologists, neuroscientists, biologists, multimedia and software engineering creating a new set of high skills for experimental wearing objects new qualities development with the core on a new way of relating to the human body in social contests. These research want in some cases stimulate a critical discourse on fashion. Experimental fashion prototyping diffusion by the web, exhibitions and performances, takes the role of a way of exploring, between the users and the objects, the system in which they exist, the reality as technology possibility.

The cross-disciplinarily research activities promise innovation that shifts focus beyond the traditional use of dresses to embrace uncertainty, interpretation, and new meaning posing a critical view on how the techno-scientific development is shared and accepted by the public. The complex performance of smart materials systems is a source of reflection and questioning on the contents and meaning of the new available media for the project.

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If in the past was well-established that «clothes are semiotic devices, machines for communication» (Umberto Eco 1986 p. 195) and their functions as essential social tool acts as an interface between our bodies and society (Barnard 2014), today explorations into smartness trough smart materials systems and wearable technology impact socially and culturally with implications in term of experience, identity and audience.

Referring to the Gilles Deleuze's (1988) concept of "theater of materials" as a space of senses, and space for relationships, the plus that smart material systems offer is the augmented performance experience in the relationship with the wearing body, as well as between people wearing and other interaction. Their performativity is at stake when we interact with objects and surfaces, and when we can control their behavior. The complexity of the forms of interaction makes the electronic material a source of reflection and questions not only the elements that make up the medium of electronic and reactive material, but also their content and meaning (Heinzel 2014). Design, operating as a bridge between different disciplines and technology, as well as the physical and digital dimension of reality, is shaping hybrid objects, dynamic, autonomous almost alive with proactive and interactive behavior. Designers are now expanding their roles from shaping existing reality, to creating and growing a new ones (Ferrara 2017).

What then in terms of perception? What more concerning the impact generated by wearing a haptic and *almost-living* dress?

We usually interact with objects of everyday use according to meanings and shared knowledge, through which we almost automatically identify functionalities, performances and even the degree of trustfulness (Russo 2018). So far, products and wearable accessories have not been designed to respond and actively interact with body stimuli, as the main performance associated to their direct function has been that of adorning and eventually ensuring comfort and protection.

The experimental fashion, like those of haptic, emphatic and bio-smart dresses, opens up new possibilities since they embed smartness as well as aspects of organic systems like motion, responsiveness, proactive behavior, and connectivity to such an extent as to be possibly defined as almost-living objects. In the case of haptic dress the technology expands the human sensory experience with versatile extra-sensory transducers that give us a multi-sensory user experience. The design develops and moves our visually emphasized design culture towards an increasingly multi-sensory design environment. In fact, the study on synesthesia has clarified that human sensory perceptions are not an objective reproduction of reality, but instead an inference that the brain draws from the signals it receives. This discover is going to change drastically our interaction with the reality and with the objects in term of envisioning how *Next Design Scenario* may look like.

Shifting our discourse on the Communicational and Aesthetics side, we can question then some issues related to such a new or even next generation of highly technical wearable concepts reminding that, according to current society setting, a dress is not requested to externalize more than what is already codified. It can only provide eventually only some subliminal messages. In addition, a dress is not allowed to be a sharing tool up to such an intimate and private level, likely to release details to unsuitably affect the other subjects involved in the communication process. It is not entrusted to deliver so clearly information about the emotional state of a subject (Russo, 2018). On this purpose it is relevant to remind that despite any stereotype or assumption, technology indeed participates in the human condition and just like human-human communication, technology and humans act and react (Cho and Park 2013), and such a point is likely to exponentially grow further if considering the increasing ability of programmed smart objects to react autonomously.

Communicational issues and dynamics get even more complicated if the almost-living object is actually a dress, a sort of second skin marking a highly dangerous territory, that of intimacy, and that standing beyond the socially and culturally visible allowed. And of course we mainly refer to feelings and emotions, not just to portions of naked flesh.

7. Conclusions

It's the time to start questioning the big changes taking place in terms of diffuse smart materiality, and thinking in terms of almost-living objects, requiring then a different categorization, as they appear as also manifesting themselves as a new source of interaction and behavioral reference for the user. Several articles have already opened up, for instance, a discourse on the impact of A.I. and Robotics, since the very early stages of their implementation, aiming to build up a sort of baseline to further research (Dirican 2015). Smart materials and their increasing applications deserve the same kind of attention.

The implementation of smart material has indeed created a new and unedited category of reactive objects, able to read our facial expression mimic once exclusive prerogative of human beings and animals, and to mimic our felling, or increase our sensory experience toward components of reality not perceptible by the human sensory system. In terms of perception, displacement and, of course, language association and dynamics, such a shift in perception discloses as a challenging frontier to be analyzed further. Indeed, all the references linked to the sphere of what is visceral, behavioral, reflective (Norman 2004) has so far been listed on the user rather than on the object side. At least a slight shift in perspectives is now needed, as a society in which humans and robots will have to coexist, it is no longer an episode of fiction, but mere reality and it is then necessary to investigate all the aspects that regulate their relationship, in order to ensure an ethical dimension and an effective benefit for people (Germak et al. 2015). Objects themselves do take a big part in world transformation (Floch 1995), and so, now more than ever, the fact of becoming deeply aware of how such a new generation of "things" is progressively redesigning the space we live in and consequentially the language we speak and the gesture we daily use, appears as a main issue to deal with. Several unedited aspects emerge while starting to analyze intelligent systems and human interaction. Quite an interesting point, arising as a relevant one, is certainly that of the dimensional scale of the almost-living objects or the robots human beings have to interact with. Dimension indeed discloses as a main parameter in terms of empathy, affection, emotional reaction/involvement, trustfulness or rejection (Cardoso 2012; Beyaert-Geslin 2015), but what appears also extremely determinant specifically in relation to consistency, it is consequentially the specific function assigned.

Art and design are increasingly taking a center stage in the philosophy of technology (Vial 2018) and the analysis of all the influence produced by innovation and technological know-how on our moral and societal values, especially concerning Smart Experience (Ferrara and Russo, 2018) and Smart Aesthetics (Russo and Ferrara, 2017) is still a field requiring further investigations.

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