Art
Art direction
Company
Conceptualisation
Crowdfunding
Design
Design education
Design engineering
Engineering
Formal design
Human factor
Industrial design
Innovation
Interactive design
Market
Medical devices
Nanotechnology
New media
Open source
Product design
Product development
Production
Project
Prototype
Smart products
Social design
Strategy
Sustainability
Sustainable design
Usability

Invisible aspects
Materials
Metadesign
Perception
Sensorial research tools
Synesthetic perception

Beatrice Lerma
Doriana Dal Palù

"We can affirm that the invisible aspects of design are linked to product sensory attributes that are closely correlated with these instrumental measures"

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Material (and product) sensoriality: Can perceptive evaluations strengthen the meta-design phase?

Products are no longer asked to perform only based on how they performed mostly in the past. They are now expected indeed to consider contemporary social changes and deliver "soft" and non-visual performance, such as greater sensory expression and complex performances, in order to improve the quality and affordability of user experience. This renewed focus on the "invisible aspects of design" generates a space of scientific interest in the design domain, focusing on the need to learn, develop and spread the most suitable tools and methodologies to support the sensory-oriented project, and integrate this fundamental requirement in the early stages of product (or service) design, in other words, focusing on the sensory aspect since the meta-design phase. This paper will present a first overview on the theme of designing the perceptive aspect of a product, showing how this topic has evolved over the years and how material libraries and products themselves are focusing the proposed information and their features toward this aspect. A second part of the work will present a set of tools and methods, driven both from the qualitative and quantitative approach, to be used by designers in order to investigate the issue of perceptive evaluations, always bearing in mind that human beings are the key figures in this process. Subsequently, some crossed-senses tools are presented, as well as several further investigating tools able to define the synesthetic or global perception of a product. Finally some conclusions on the opportunities offered by these methods are discussed.

A new premise: multiplying the perception

Today, the issue of multisensory product experience appears to be at the forefront of design research [Schifferstein & Desmet, 2008; Lerma, De Giorgi & Allione, 2011], as well as in consumer science [Norman, 2004]. The experience of any product, physical object, service or space, derives from the multisensory response by the subject that comes into contact with the product itself. For many years, the immediacy and spontaneity of the visual approach in perception has supported several theories [Berendt, 1988] affirming life in a real "eye culture". Nowadays, these theories are overtaken thanks to the proven collegiality of every sense in the perception process (Image 1); indeed, in real life it is very difficult to delimit perceptive experiences, uninterrupted and often unconscious, to one single sensorial channel [Bandini Buti et al., 2010].

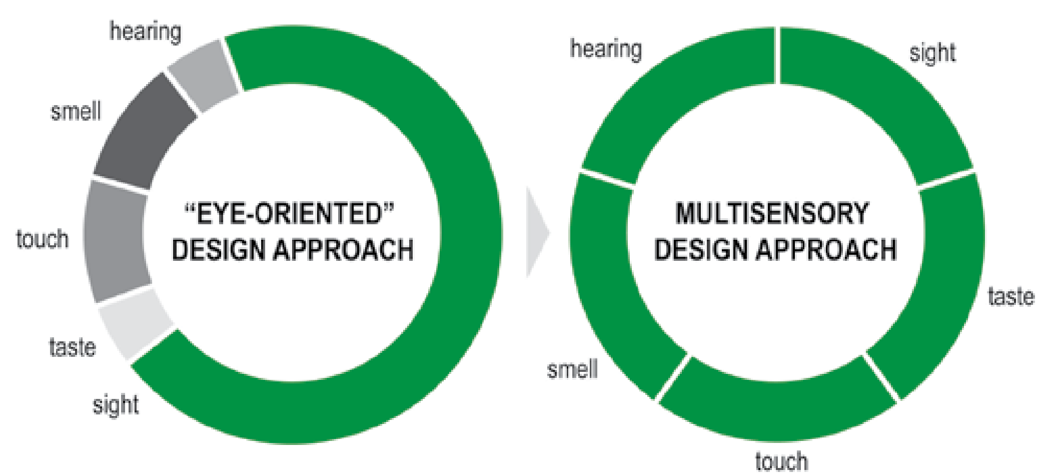
Thus, the senses of touch, smell, hearing and taste have been rediscovered in the design phase, giving birth to more or less valid examples of products able to interact with a holistic sensory level with the user [Lévy, 2013; Wastiels et al., 2013]. So the question is: can sensations and perceptions be measured and evaluated in order to strengthen the meta-design phase?

A glance at the designed world

This renewed interest in the "invisible aspects of design" [Ferreri & Scarzella, 2009] generates a space of scientific interest in the design domain [Celaschi, 2008], focusing on the need to learn, develop and spread the most suitable tools to support the sensory-oriented project, and integrate this fundamental requirement at the early stage of the design of the product (or service), in other words in the meta-design phase [Germak, 2008].

More in depth, we can affirm that the invisible aspects of design are linked to product sensory attributes that are closely correlated with these instrumental measures [Rognoli & Levi, 2011]. For example, tactile material properties, such as softness or warmth, are linked to instrumental measurable physical properties such as Young's module and thermal conductivity. Despite that, as Schifferstein and Wastiels underline [Schifferstein & Wastiels, 2014], none of the current measuring methods or models can describe a material-perceived softness. Moreover, material-perceived properties (gloss, softness, roughness, sound qualities) are difficult to measure but considered as an important collecting method in different material libraries (real and virtual library of innovative materials) and as an aspect to be considered during the choice of a material for a certain project.

▼ Image 1. The evolution of the sensory design approach: from the primary role of sight to a more balanced global approach, considering every sense. Credits by the paper authors.



▲ Image 2. Plopp stool, by Oskar Zieta for Hay (2008). Credits by Zieta Prozessdesign – Museum für Gestaltung, Zürich.

▲ Image 4. Sensory Cutlery Collection, by Jinhyun Jeon (2012). ©2007-2015 JinhyunJeon.

▲ Image 3. Czarka / Bowl, by Marta Niemywska-Grynasz and Dawid Grynasz for Meesh (2015). Credits by Marta Niemywska-Grynasz.

► Image 5. Suitcase Symphony by Jeriël Bobbe for Bloondesign (2011). Credits by Jeriël Bobbe.

Functional properties will tend towards sensory perception and the sensory perception will be technical [González & Peña, 2013]. Industry can no longer ignore the sensory features of a product, whether it is a car or a toy, and choosing the most suitable material is a key factor in the revival of a good product and in its linked sensory experience.

In recent years material libraries have developed different methods to define the sensory characteristics of their catalogued materials. For example Materia in The Netherlands, Materfad in Barcelona, MATto materials library of the Department of Architecture and Design DAD - Politecnico di Torino [Lerma, De Giorgi & Allione, 2011; De Giorgi, Allione & Lerma, 2010], Materiali e Design in Politecnico di Milano [Rognoli, 2005] and Mat&Sens by CerteSens in France.

Simultaneously, designers conceive specific products in order to create new sensory or synesthetic experiences in users, far subtler and often more unconscious than the well-known "wow-effect" that states the desire to shock (and communicate with) the user. An example of a product designed exploiting the "wow-effect" is the Plopp stool by Oskar Zieta. This stool is a real paradox. Although the furniture seems very light, its construction obtained by hydro-formed metal is solid and durable (Image 2). With regard to unconscious sensory experiences, for example, Polish designers Marta Niemywska-Grynasz and Dawid Grynasz conceived Czarka / Bowls (2015) for drinks whose walls are covered with a three-dimensional pattern. By also avoiding a slippery handle, apparently this pattern alludes to the textile world. A hot tea bowl can then evoke a warm hug by a woollen sweater (Image 3). Focusing on a more evident sensory design process, it is impossible not to quote the Sensory Cutlery Collection by Jinhyun Jeon (2012): the Sensory Spoon Set, in pure-white ceramic, has been designed to stimulate all the senses when eating. From the thickness of the handle to the volume mass of the spoon, each of them evokes a different eating effect (Image 4). Finally, another important example of sensory product is Suitcase Symphony by Jeriël Bobbe (2011), a floor that cures the boredom of monotonous walkways in airports and railway stations. Sounds are obtained thanks to ribbed wood pieces that can be arranged like musical notes; the distance between the grooves corresponds to pitch, while the depth of the ruts determines volume (Image 5).

> "What characterizes the complexity in perception is really the intrinsic multidimensional nature combined with a subjective attitude"

Scientific approach vs. empirical approach

Having acknowledged the importance of perceptive features of materials, multisensory aspects have become important in the classification of materials in material libraries. In these archives, material classification is based either on a technical approach (reflectivity, heat conductivity, thermal properties, etc.) or on an empirical perceptive criteria [Lerma, De Giorgi & Allione, 2011]. Unfortunately it was evident, in the wide range of classification criteria relating to the sensorial characteristics of the materials, that there was a lack of a common language and vocabulary and a mainly empirical approach that is not based on scientific criteria. Various are the methods and the tools which can be used to define the sensory properties of materials. Some material libraries use sensory words and specific terminology to describe and catalogue materials from a sensorial point of view. Often materials are manipulated by the classification team and, as a result, the valuation is based only on the experience and knowledge of the team member. A good procedure for material libraries would be to make use of trained 'materials tasters' to define the expressive-sensory properties of materials. Moreover, every institute develops its own classification and assessment system [Rognoli, 2005; De Giorgi & Lerma, 2010; Lucibello, 2006]. It is thus not easy to understand the meaning of sensory terminology (to what degree is a foam soft or rough? Which is the value of a low-medium-high scale?) and which are the methods and tools used to define it. From a design point of view, it's necessary to deal with the topic of sensory perception with scientific and interdisciplinary breadth.

▲ Image 6. One of the tools for analysing the sight qualities: the NCS Gloss Scale based on NCS - Natural Colour System®©. NCS Colour AB, Swedish society founded in 1946, holds and is responsible for the rights related to the NCS chromatic system - Natural Colour System®©.

This work will present a complex and wide range of methods and tools available on the market which could be used for sensory perception design in the meta-design phase. In conclusion, some examples of the research carried out at the Politecnico di Torino will be briefly described in order to present the research that adopted these tools developed in MATto - DAD Department of Architecture and Design to define the perceptive characteristics of materials and products.

Possible methods and tools for perceptive evaluations

The evaluation of the "*perceptive dimension*" [Germak, 2013] of products consists of methods and tools (qualitative and quantitative) to measure the consumer's "*quali-quantitative*" perception of the sensory characteristics of different products.

Qualitative and descriptive analyses are strongly connected with human perception [Berglund et al., 2011]. This assumption discloses the matter of soft metrology. Soft metrology is defined as the set of measurement techniques and models which enable the objective quantification of properties which are determined by human perception.

THE "TASTER" ROLE

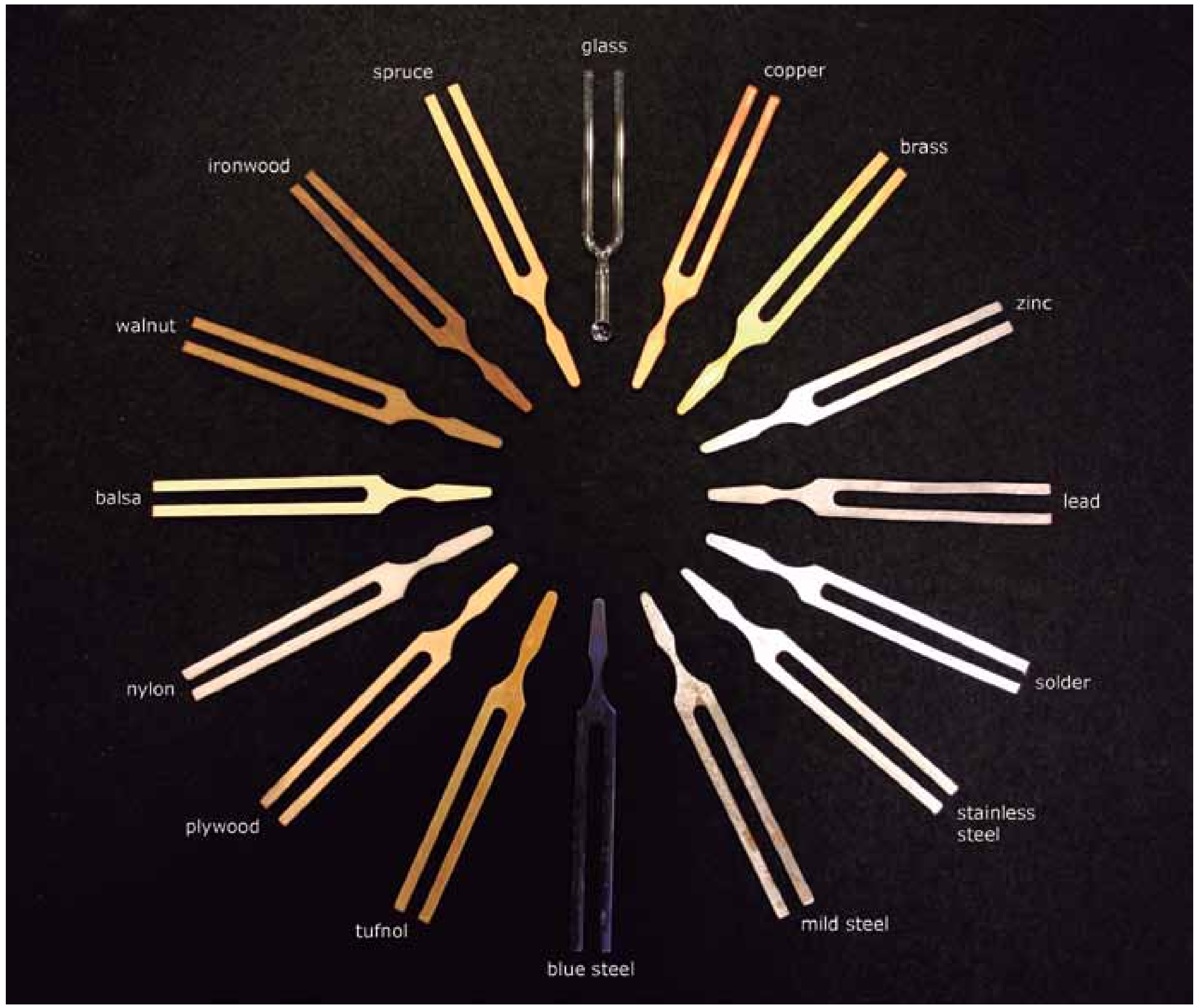
What characterizes the complexity in perception is really the intrinsic multidimensional nature combined with a subjective attitude. Recently, sensory evaluation techniques have been developed to reveal detailed information about perception of products [Pagliarini, 2002]. Both in soft metrology and in sensory evaluation, the human being is accounted as the measuring instrument, thanks to his involvement in focus group and testing sessions.

The common denominator of the presented methods is involving a qualified sensory panel of people (the "*tasters*", e.g. a group of experts, appropriately guided in acoustic sensorial analyses) trained to detect and record sensory perceptions in standard test conditions. Similarly to a measuring instrument, the trained assessors provide accurate and statistically representative results, becoming in this research approach the real qualitative judges of the perceptive characteristics of the material/product in question.

Devices are always used in the presented methods in combination with questionnaires, focus groups and semantic differentials: tools for sensory analysis are used as an additional instrument for assessing meta-project or product concepts to reinforce or weaken judgements, anticipating what could be the indications of choice made by the public for whom the product is intended. Finally, some applications of this method and these tools, even by matching two or more tools and senses (for example analysing sight and touch together) to the current and past researches unfolded in the MATto materials library

▲ Image 7. One of the tools for analysing the hearing qualities: the SounBe tool. Credits by the paper authors.

▼ Image 8. The Tuning forks. Credits by Zoe Laughlin.



of the Department of Architecture and Design DAD - Politecnico di Torino will be presented.

QUALI-QUANTITATIVE TOOLS FOR PERCEPTIVE EVALUATIONS

Sensory analysis allows describing products and materials from visual, auditory, olfactory, tactile and gustatory points of view, by the use of sensory vocabulary, value scales and specific tools for each sense:

▲ Image 9. The Voice gesture sketching tool. Credits by Karmen Franinovic.

EVALUATING SIGHT QUALITIES

— **Pantone scale®**: proposes an excellent method to describe a colour based on sample comparison; it provides special colour selection tools including comparative tables and descriptions of the identified colour. In fact, the Pantone system works by comparing the material to be tested with samples provided by the company itself: once the chromatic reference is established, it is described using the code for each colour sample;

— **NCS Gloss Scale**: based on NCS - Natural Colour System®©, this scale is a tool that measures the qualitative brightness/opaqueness of surfaces (direct comparison between the material to be tested and the various samples provided) and their quantitative brightness/opaqueness (thanks to the measurement on the front of each sample provided with the tool). The gloss level can vary from 0 to 100: level 0 corresponds to a totally opaque surface, and 100 to a shiny glossy black sheet of glass; (Image 6)

— **NCS Lightness Meter**: always based on NCS - Natural Colour System®©, this tool represents an evolution of the NCS Gloss Scale, visually recording colour luminosity. It is has 18 samples of neutral grey taken from the 1950 standard NCS colours. The NCS Notation, the NCS lightness, and the value of the luminous reflectance factor is provided for each of the samples;

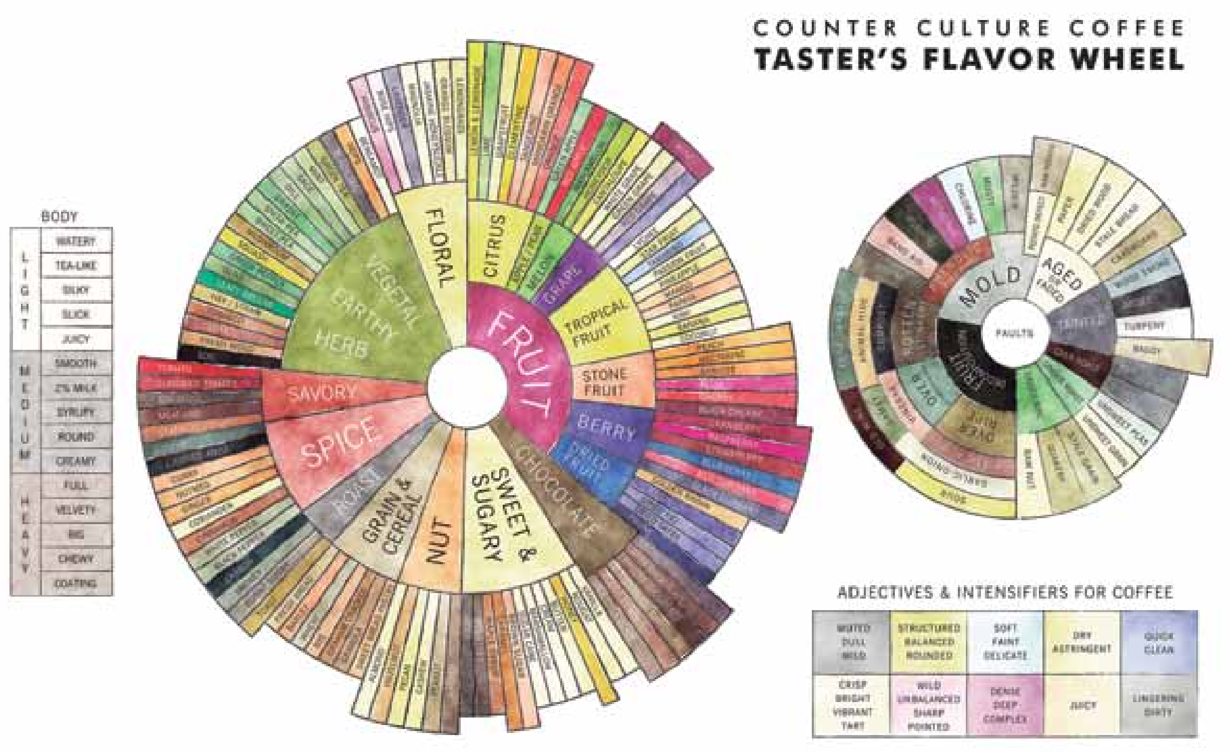
— **Spectrophotometer**: can be used to determine the absorption spectrum of a substance, which can be portrayed in a diagram showing the intensity of radiation absorbed according to the wavelength and where it is easy to recognise maximum absorption of the substance along certain wavelengths.

EVALUATING HEARING QUALITIES

— **SounBe**: a toolkit and a method both developed in Politecnico di Torino as a support tool for those designers aiming at the right choice of the most suitable material to his design project [Dal Palù et al., 2014]. Following this method, they will be able to split the sound matter in main factors and gather some useful meta-project advice related to their needs. Finally, a new planning approach to sounding objects will generate new planned soundscapes, avoiding increasing noise pollution; (Image 7)

— **Tuning forks**: sixteen tuning forks of different materials were developed at the Institute of Making (London) in order to test the comparative acoustic properties of different materials and to understand how these are experienced through perception [Laughlin & Howes, 2014]. The form is constant and the material changes: the acoustic/sound performances of the forks are different (and are judged different) according to the various physical parameters, density and elastic modulus; (Image 8)

— **Sound level meter**: is an instrument which measures sound pressure level, usually calibrated in decibels. By measuring sound pressure, the sound meter creates the signal to obtain the descriptor indexes typical of noise measurements: level of sound pressure (Lp), equivalent level of sound pressure



▲ Image 10. The Counter Culture Coffee tester's flavour wheel, to describe aroma and taste of coffee. ©2013 Counter Culture Coffee.

(LAeq), percentile levels (LN), etc. The market offers several sound measurement systems, even if each system can be schematically reduced to three components: a microphone, a data processing unit, and a data interpretation unit;

— **Voice gesture sketching tool**: this tool has been developed for sketching and improvising sonic interaction through voice and gesture: it has the capability of recording the voice through a microphone as well as capturing the gesture performed, coupled to the sound (Image 9).

EVALUATING SMELL QUALITIES

— **Flavour wheel (Aromas)**: derived from the original Flavour Wheel which Danish chemistry Morten Meilgaard conceived to facilitate the description of aromas and tastes by assessor 'judges', the aroma side of this tool has been applied to different products (e.g. coffee, wine) in order to better classify on three levels the aromas found. Very general terms are located in the centre, going to the most specific terms in the outer tier (for example: fruity aroma → citrus fruits → lemon; fruity aroma → soft fruits → black currents; woody aroma → resinous wood → oak; vegetal aroma → plants → eucalyptus, etc.); (Image 10)

— **Sensory Box Explorer**®: developed by the Italian Centro Studi Assaggiatori, the Sensory Box Explorer® is a toolkit born to stimulate active scent exploration, through which everyone can train their olfactory abilities. It comprises twenty olfactory standards which reproduce aromas present in ordinary life experiences of our society and representative of the main aromatic families (floral, fruity, green, spicy, etc.); (Image 11)

— **Electronic nose**: the electronic nose is a tool, which tries to replace the human olfactory system and make measurements objective. The sophisticated software developed for these 'recreated noses' is able to file and preserve the incredible number of perceived smells classified by the electronic nose.

EVALUATING TOUCH QUALITIES

— **TouchFeel**®: a tactile reference frame developed by France-based automaker Renault (called Sensotact) that analyses and classifies the tactile perceptions of materials. This tool is being used in a variety of industries including textiles, toys, packaging and automobiles, among others. It provides a common language that enables designers and suppliers to communicate using clear, precise definitions of tactile qualities. It is also used to measure tactile sensations, certify the conformity of an end product with its prototype, and determine which tactile qualities are most likely to influence a customer to buy a product. Currently, the tool has been further developed by the French ExpertiSens®; (Image 12)

▲ Image 11. The Sensory Box Explorer. ©2012 Centro Studi Assaggiatori Soc. Coop.

▲ Image 12. TouchFeel®: pictures of the previous version (Sensotact developed by Renault). Credits by the paper authors.

— **BioTac**®: the BioTac® mimics the physical properties and sensory capabilities of the human fingertip. Initially developed by researchers at the University of Southern California, and now by SynTouch, LLC, the BioTac®, with its advanced human-like tactile sensing, is the leading product in machine touch. Identical to human touch capabilities, it is capable of sensing force, vibration and temperature.

EVALUATING TASTE QUALITIES

— **Flavour wheel (Taste)**: a fourth version of the wheel created by Morten Meilgaard is reserved for the following tastes: mouthfeel, bitter, salt, sweet, sour/acid, musty; always organized on three levels, from general terms in the centre of the wheel it's possible to move to the most specific terms in the outer tier (for example in coffee taste wheel: sweet → mellow → delicate; salt → bland → neutral). Also in this case, different flavour wheels have been developed for food and drink, for example for coffee, beer or cheese; (Image 10)

— **Electronic Tongue**: it is a new technical tool, one of the many that can be used to identify organoleptic properties. A sommelier recently tasted fifty-three wine samples: without making even one tiny mistake, he guessed the grape species, the region the bottles came from, and the organoleptic properties of each sample (fresh, fruity aroma, high acidity, intense ruby red colour, and the insidious presence of mould in the cork).

CROSSED-SENSES EVALUATION TOOLS

Furthermore, sensory analyses are sinestesycally ex-post validated through the use of specific equipment, which offers some important data regarding the user's attention to the observed product (submitting real or virtual prototypes to tasters). This phase can be once more carried out using the previously presented tools or, specifically, adopting one of the following new tools to verify the consumer's response to the submitted stimulus.

The tools presented below stemming from different fields (psychology, visual systems, product, educational and market research) are proposed as support tools for design phases and a validation method for the sensory analysis completed by using the visual, auditory, olfactory, tactile and gustatory tools, also thanks to the use of qualitative and analytical methods such as questionnaires, focus groups and semantic differentials.

▲ Image 13. Eye-tracking device during tests carried out in MATto, Politecnico di Torino. Credits by the paper authors.

— **Eye tracking**: it provides robust data quality and state-of-the-art visualisations and metrics showing where, when and what people look at. The instrument features special glasses following eyeball movements, and a software decoding the data. All raw eye tracking data is easily exported for more in -depth analysis; (Image 13)

— **Revel**: a wearable tactile technology, based on Reverse-Electrovibration, that modifies the user's tactile perception of the physical world. Revel can add artificial tactile sensations to almost any surface or object, such as furniture, walls, wooden and plastic objects, and even human skin. As Bau and Poupyrev explained about Revel, surfaces are perceived in different ways, and this difference can be used for augmented reality [Bau & Poupyrev, 2012]. For example, a square wave feels more intense and sharper than a sine wave; the difference is comparable to sliding the finger on a grid of smooth versus sharp bumps; in fact, REVEL is an augmented reality (AR) tactile technology that allows changing the tactile feeling of real objects by augmenting them with virtual tactile textures using a device worn by the user. Moreover, the Revel conductive surface could be also considered an instrument useful to define more tactile-attracting product areas [Buiatti, 2014];

— **Face Reader**®: developed by the Dutch company Noldus, this software has been developed to observe the instinctive response of a subject to a stimulus, but focusing specifically on the answer given by the facial expression. Thanks to a virtual network of 500 points, the software evaluates the relative position of points and the results in six expressions encoded using a shared meaning (amused, incredulous, angry, etc.). Even in this case, the software can be used to test the instinctive response to the stimulus from a point of view of both quality and quantity; (Image 14)

— **The Observer**®: also this software has been developed by Noldus to allow the observation of a subject's behaviour in a specific circumstance (for example in the purchase phase). Through the use of a webcam, the software allows collecting data about the gestures that the subject does, the observation time, the phase of reflection on the product by comparing them with the trend generated by the set of subjects analysed. It is a particularly significant part of the marketing, but may be used in general to evaluate the subject's response to any stimulus;

— **EEG**: electroencephalograph is a measuring tool used in user experience researches. EEG data could be used by researchers [Zheng, Dong & Lu, 2014; Romano Bergstrom & Schall, 2014] in combination with eye-tracking data, to define interface areas that were looked at and that were emotionally engaging;

— **PrEMO**: it is a tool designed in order to assess emotions evoked by products. PrEmo is a non-verbal self-report instrument designed to understand

▲ Image 14. Face Reader® by Noldus. Credits by Noldus Information Technology, bv.

and evaluate the emotional response to customer products. Instead of relying on the use of words, respondents can report their emotions with the use of expressive cartoon animations. In the instrument, each of the fourteen measured emotions is portrayed by an animation of dynamic facial, bodily, and vocal expressions [Crippa, Rognoli & Levi, 2012; Desmet, 2003; Lokman et al., 2013].

Conclusion

This quick overview aims to recall just some of the design tools available to designers in order to address the issue of multisensory products. Every tool has specific strengths and weaknesses. Some of the tools are more "designer-oriented", others may not be so easy to use, but the main purpose of this collection is to make readers consider the range of possible research paths on the theme of perception.

At the Politecnico di Torino (DAD Department of Architecture and Design) during different research initiatives carried out in the last years [Allione et al., 2012] has been presented a method that integrates qualitative and quantitative tools and techniques (for example, from SounBe, to questionnaires, semantic differentials, brainstorming, etc.) in order to help designers create products that satisfy the user's demand for perceived quality: this method (Image 15) has been used to perform the analysis on car seat concepts [Lerma & De Giorgi, 2011] from the tactile and visual point of view, to analyse packaging and the assessment of perceived sustainability [Lerma, De Giorgi & Germak, 2015] and to understand the perception of sustainable luxury.

Furthermore, there is no perfect tool for all applications. It's up to the designer to interpret the research question and to focus his research towards the most suitable tool for this project. In fact, for each research project the designer can choose between an *ex-ante* or an *ex-post* approach, deciding in each occasion whether to focus his sensory analysis before starting with the design process (with the aim of collecting some hints for the meta-project phase), or to carry out these sensory research projects such as the testing phase in order to highlight several possible designing criticalities to be subsequently recalibrated.

Anyway, in both the *ex-ante* and in the *ex-post* approaches—and both in the case of qualitative or quantitative tools—it's necessary for the designer to always bear in mind the final goals of the analyses. Since these tools are driven from very different application fields such as medicine, chemistry, marketing, etc., each reply of the sensory research has to be interpreted and read from a project point of view.

"The main brief of the sensory research has to be very clear to the designer, as well as the results he/she wants to obtain from the research itself"

In other words, the main brief of the sensory research has to be very clear to the designer, as well as the results he/she wants to obtain from the research itself.

Finally, both the multiplicity of the application fields and the dual approach (both qualitative and quantitative) of these tools and methods represent the main strength for sensory, perceptive and synesthetic research projects, and an interesting starting point to deal with material (and product) sensoriality.

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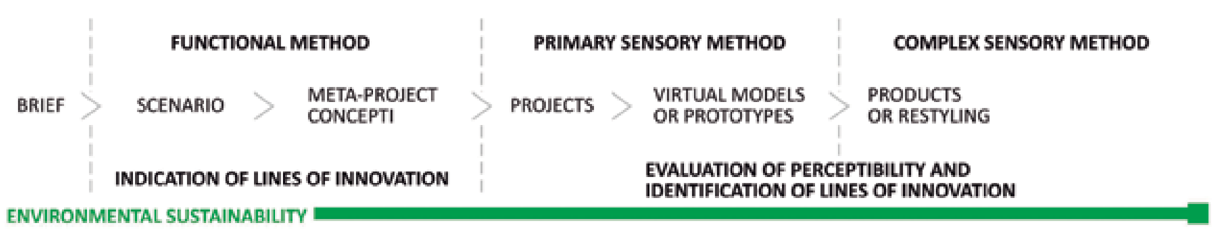
▾ Image 15. MATto method developed to analyse materials and products: sensory perception and sustainability issues. Credits by authors of the paper.



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