The Senses: abrasive, buttery, clammy, doughy, effervescent, Design foamy, gurgling, hissing, icky, jangling, knotty, lemony, minty, nubby, oily, Beyond pungent, quiet, rank, silky, tart, unctuous, viscous, waxy, xilinous, yeasty, zingy Vision

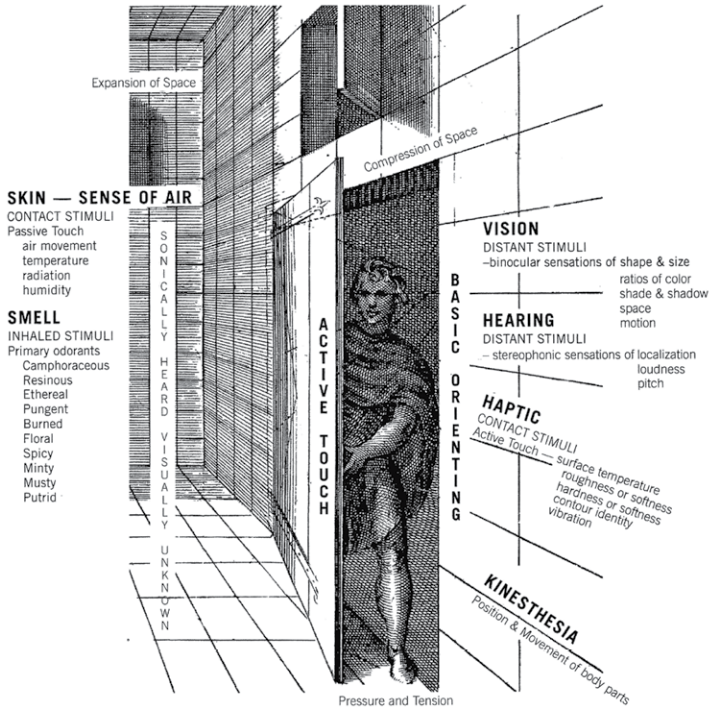
The Senses:
Design Beyond Vision

Ellen Lupton & Andrea Lipps

COOPER HEWITT, SMITHSONIAN DESIGN MUSEUM

& PRINCETON ARCHITECTURAL PRESS

NEW YORK



A black and white engraved drawing shows a figure opening a door into a room. Labels point to aspects of the room: Skin—Sense of Air. Smell—Inhaled Stimuli. Vision—Distant Stimuli. Hearing—Distant Stimuli. Haptic—Contact Stimuli. Kinesthesia—Position and movement of body parts.

JOY MONICE MALNAR AND FRANK VODVARKA, RANGES OF THE SENSES, from *Sensory Design*, University of Minnesota Press; © 2004 by Joy Monice Malnar and Frank Vodvarka

Why Sensory Design?

Ellen Lupton & Andrea Lipps

Reaching beyond vision, this book is a manifesto for an inclusive, multisensory design practice. Sensory design activates touch, sound, smell, taste, and the wisdom of the body. Sensory design supports everyone's opportunity to receive information, explore the world, and experience joy, wonder, and social connections, regardless of our sensory abilities. This book documents extraordinary work by some of the world's most creative thinkers, and it gathers together ideas and principles for extending the sensory richness of products, environments, and media.

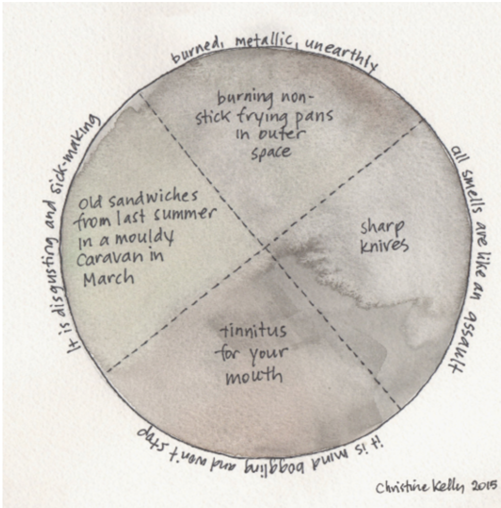
This book accompanies the exhibition *The Senses: Design Beyond Vision*. As curators at Cooper Hewitt, Smithsonian Design Museum, we sought out work and insights from designers, researchers, and users. We searched for artifacts that could be directly experienced by the museum's visitors. We learned about the fusion of mind, body, and sensation.

The senses mix with memory. From infancy, human creatures engage in countless acts of lifting, licking, touching, sniffing, throwing, dropping, hearing, balancing, and more, constantly testing the edges of physics to understand (or "make sense of") the world we were born to discover. The brain fires neurons, prunes synapses, and forges pathways. Thus meaning and memory take form. When we encounter an oddly shaped coffee cup or an updated operating system, we don't see it as completely alien but focus our attention on disparities between what's new and what we've encountered in the past. What would this page taste like if you licked it? What sound would this book make if you dropped it? We can imagine these sensations without needing to enact them. Prior experience tells our brains what to expect.

The senses move us through space. The eye or ear is not a fixed camera or a microphone wired to a wall; our sense organs are connected to a head that turns, arms that reach, and bodies that wander and seek.[1] The sounds, smells, and shifting shadows of a room or a streetscape help orient this knowledge-hungry body. Sensory experience hits us from all directions. Traditionally, designers focused on creating static artifacts — the monument, the vessel, the elegant monogram, or the essential logotype. Today, designers think about how people interact over time with a product or place.

The senses merge and mingle. As kids, we learn to think of the five senses as separate channels, like five radio stations playing at once. Some stations buzz along in the background, while others dominate. The real picture is more complex. As the brain combines different modes of information, the senses mutually change one another. A cold, fizzy soda tastes better than a warm, flat one. A bar of chocolate wrapped in richly patterned paper primes our desire for the bittersweet goodness within. Golden light makes a room feel peaceful and warm, while cool daylight hues charge it with energy. Designers consider interaction of bodies and things. What sound does a chair make when it scrapes along the floor? How hard does a button need to be pressed to register a response? How much does a surface flex when we push against it?

The senses are unique to every person. Some people have smell receptors that make broccoli taste appallingly bitter; to others, cilantro tastes like soap. Some people have a diminished sense of smell. This condition, called *anosmia*, vastly diminishes the pleasure of eating and of otherwise exploring the world; it affects six million Americans. Christine Kelly, who became anosmic after a sinus infection, creates smell wheels that illustrate how her sense of smell has been distorted—smells that should pique the appetite or calm the nerves became noxious and muddy.



A circle divided into quarters is hand-colored in brownish gray and labeled with texts such as "burning non-stick frying pans in outer space." Texts around the edge include "all smells are like an assault."

ANOSMIA: THE MONOTONY OF SMELL LOSS, 2015; Christine Kelly (American and British, b. 1959); Watercolor and ink; Courtesy of Christine Kelly and ink; Courtesy of Christine Kelly

People with color blindness see red and green or blue and yellow as similar hues. Individuals with multiple sclerosis, leprosy, neuropathy, or severe burns can lose sensitivity to touch. Individuals with SPD (sensory processing disorder) can feel unbearable distress from tags and seams in clothing or crave constant bodily motion. Some sensory differences yield extreme pleasure. ASMR (autonomous sensory meridian response) is a delicious tingling in the scalp and spine triggered in some people by sounds such as crunching, crackling, or rubbing. In videos popular with the ASMR community, manicured hands gently crush plastic-wrapped pastries or rustle crisp sheets of paper, narrated by whispering voiceovers.

The senses trigger and amplify other senses. For people with synesthesia, the brain makes cross-connections between the senses. Music can play in color, while letters can conjure sounds or textures. Neurologist Richard E. Cytowic has devoted his career to studying synesthesia. Once seen as a rare disorder, synesthesia is now known to be a widespread condition with dozens of variations, affecting one out of every twenty-three individuals. A child with synesthesia begins establishing cross-sensory connections early in life. When learning the alphabet, a child might link the color green with words that start with *g*. Such associations become fixed for life, cemented both by nurture and nature.[2] David Genco, a graphic designer with synesthesia, assigns color, gender, and personality to numbers. In his interactive video project *Synesthetic Calculus*, video clips visualize unique ways of remembering numbers via sensory connections.

Colored numerals appear surrounded by the atmosphere of urban spaces, photographed in soft focus with a sense of movement.

SYNESTHETIC CALCULUS (STILLS), 2012; David Genco (Luxembourgian, b. 1985); Video; Courtesy of David Genco

The senses are plastic. Cytowic compares synesthesia to fireworks — a sudden spray of color is triggered by a word, letter, or sound. While synesthesia is a specific neurological condition, some degree of sensory alchemy permeates daily life. “Inwardly, we are all synesthetes,” Cytowic told us. “We just don’t notice how our senses interact.” The human mind has a gift for connecting sensations — we link tastes and colors, sounds and spaces. Some people who are deaf or blind become acutely attuned to multiple senses, using areas of the brain typically devoted to sight or sound to process other inputs. People perceive objects and spaces with sound and touch as well as with vision. People experience sound by feeling vibrations and seeing movements as well as hearing by ear.

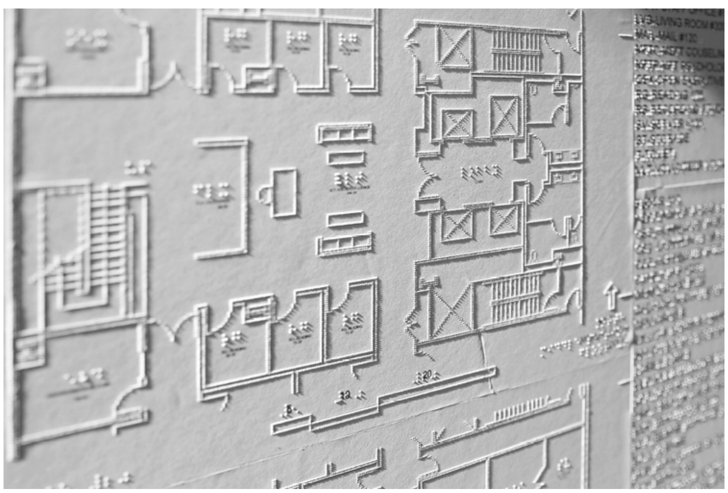
Scientists are creating sensory substitution devices that enable a blind person to convert audio signals into low-resolution mental images, or that allow a deaf person to convert a grid of vibrations felt against the skin into recognizable speech. “Lingual vision” is the ability to understand features of an object via electrical stimulation of the tongue. A lollipop-shaped stimulator placed inside the mouth can help a soldier traverse a dark night, or a diver navigate a murky sea, or a blind person perceive the outlines of objects and their locations in space. Cytowic told us, “The brain doesn’t care where the signals come from — your eyes or your big toe. Send in anything, and the brain will figure it out. Reality takes shape in the dark theater of the brain.”[3]

The senses chatter constantly with one another. Indeed, it takes serious mental effort to pull our sensations apart. It is tough to separate the sweet, sour taste of a mango from its bright, caramel-tinged aroma. Do you sometimes close your eyes when trying to decipher a faint sound or an odd aftertaste? That’s why the lights go down before a concert begins. Darkness helps us hear more clearly. Shutting out visual signals can help bring other senses into focus. In his essay “Designing LIVE,” Bruce Mau tells sighted designers, “To design for all the senses: start with a blindfold.”

The senses have long been dominated by vision. In the Western tradition, the eye symbolizes knowledge and enlightenment. Visual observation is the bedrock of modern science. Today, digital devices pump out an endless feed of graphics and text, stoking demand for quick hits of visual energy — often at the expense of our other senses. Smell sits at the bottom of the pyramid, in part because it resists attempts to be visually diagrammed, as Adam Jasper and Nadia Wagner point out in their essay “Smell.”

Sensory design rebels against the tyranny of the eye. When Finnish architect Juhani Pallasmaa published his book *Eyes of the Skin* in 1996, many architects began to question the dominance of visual form and the Western obsession with "ocularcentrism." The overbearing eye fosters detachment and isolation, breeding the harsh atmosphere of modern schoolsand hospitals.[4] Architecture, says Pallasmaa, should embrace and envelop the body with authentic materials and tactile forms. Sensory design slows space down, making it feel thick rather than thin. An intimate room reverberates with shifting shadows and surfaces wrought from wood, wool, or stone. An atrium changes with the sun. Rough walls and dense fabrics absorb clatter and din.

Sensory design enhances health and well-being. A scent player for Alzheimer's patients stimulates the appetite by releasing the smell of grapefruit, curry, or chocolate cake at mealtimes. Tactile graphics are used to communicate ideas through the sense of touch. Buildings with spacious hallways and vibrant materials accommodate everyone, including people experiencing blindness, deafness, or memory loss.



A black and white photograph shows an architectural drawing with raised lines and braille text.

TACTILE ARCHITECTURAL DRAWING (DETAIL), SAN FRANCISCO LIGHTHOUSE FOR THE BLIND AND VISUALLY IMPAIRED, 2015; Chris Downey (American, b. 1962); Embossed digital print with ink, raised lines, and braille; Printed by San Francisco LightHouse for the Blind and Visually Impaired; Photo by Don Fogg

Sensory design is inclusive. Each person's sensory abilities change over the course of a lifetime. By addressing multiple senses, designers support the diversity of the human condition. In his essay "The Inclusive Museum," Sina Bahram points out that museums have long used ramps and elevators to ensure that visitors with disabilities can enter the building, but museums often fail to offer these visitors a rich experience once they get inside. Universal design expert Karen Kraskow conducted interviews with singers, an artist, a tech consultant, an architect, a former jewelry designer, and others who are blind or visually impaired, learning how they live and flourish.

Sensory design embraces human diversity. According to the New York City Mayor's Office for People with Disabilities, inclusive design creates a "multisensory enhanced environment that accommodates a wide range of physical and mental abilities for people of all ages." [5] People sense the movement of objects, air, and bodies through touch, sound, and smell as well as vision. Acoustic designer Shane Myrbeck (Arup) notes that the classic Honeywell thermostat is an accessible design that offers an eyes-free tactile interface, while operating the digital touch screen of the Nest requires vision.

Two round thermostats are shown. One has a dial that turns; the other has a blue touch screen.

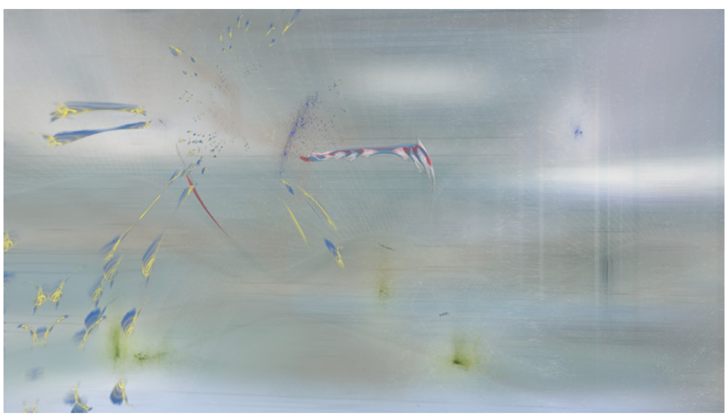
T-86 ROUND THERMOSTAT, 1953; Henry Dreyfuss (American, 1904–1972); Manufactured by Honeywell, Inc. (Minneapolis, Minnesota, USA, founded 1906); Metal, molded plastic; 4.5 × 8 cm diam. (1 3/4 × 3 1/8 in.); Gift of Honeywell Inc., 1994-37-1; Photo by Hiro Ihara © Smithsonian Institution.

NEST LEARNING THERMOSTAT, 2012; Tony Fadell (American, b. 1969); Manufactured by Nest Labs, Inc.; Forged stainlesssteel, glass, injection-molded plastic, electronic components; 4.1 x 8.1 cm diam. (1 5/8 × 3 3/16 in.); Gift of Nest Labs, Inc., 2013-19-2-a,b; Photo by Ellen McDermott © Smithsonian Institution

Smartphone interfaces promote accessibility for blind and low-vision users by combining audio and haptic signals with touch-screen technology. Apple's iPhone has a built-in screen reader and an array of accessibility modes — available to every user of every device. Steven Landau and Joshua Miele are creating tactile models, maps, and diagrams, while Liron Gino has designed a music player that translates sound into tangible vibrations.

Sensory design considers not just the shape of things but how things shape us—our behavior, our emotions, our truth. Sensations respond to an insistent, ever-changing environment. When our body presses into the cushioned surface of a chair, both body and chair give and react. We grab objects in order to use them as tools for breaking, bending, mashing, or joining together other objects and materials. Tools are active extensions of our sense of touch. Tasting food is more than a chemical response—it involves the muscular, skeletal action of crushing and transforming matter. We use our senses to change our world.[6]

Sensory design honors the pulse of living, breathing spaces. The loudest car on a train is the “quiet car.” The carriage shakes along the tracks and shudders against the damaged infrastructure. Talking is forbidden, but you can hear the clink of ice, the crackle of food wrappers, and the whir of people slurping, sipping, breathing, and snoring. Libraries, too, are quiet places filled with sound. Karen van Lengen and James Welty explored the sounds of the New York Public Library, the Seagram Building, and other iconic interiors for their 2015 project *Soundscape New York*. Van Lengen created drawings inspired by sounds in space, from a rolling cart to books opening and closing. Welty created a temporal animation of van Lengen’s drawings.



A colored drawing depicts a gray, airy atmosphere punctuated with flashes of color.

NEW YORK SOUNDSCAPE: NEW YORK PUBLIC LIBRARY (STILL), 2015; Karen van Lengen (American, b. 1951) and James Welty (American, b. 1950); Animated film; Collection of the Museum of the City of New York; Courtesy of the designers

Sensory design is grounded in phenomenology. This field of thought explores how humans and other creatures perceive the world. Philosophers in the early twentieth century brought new attention to bodily perception. Scientists and philosophers since the Renaissance had separated mind and body, distrusting sensation as mere illusion and favoring instead objective mathematical laws. Phenomenology situates knowledge in the body: sensual encounters enable consciousness. [7] The human organism is an open, breathing membrane in continual contact with its surroundings. The earth moves as we move along it. Dust swirls, leaves crush, and molecules shiver into waves of sound. As other creatures cross our path, we ripple into action to create sounds and gestures.

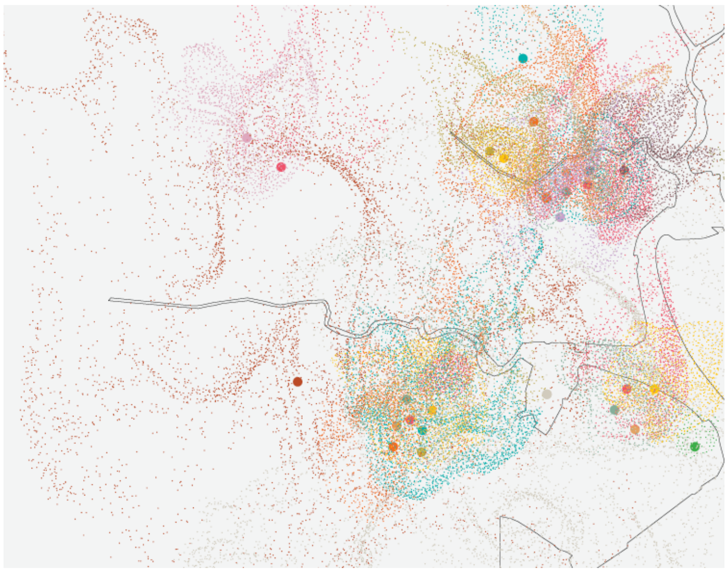
Sensory design knits together time and space. When we look at a building, our gaze darts from its small details to its larger volumes to create an understanding of the whole. In their landmark book *Sensory Design*, Joy Monice Malnar and Frank Vodvarka describe the different ways we encounter architecture.[8] We judge the scale of a building in relation to our own limbs and torsos. As we pass through a doorway, space hugs us tight and then lets us go. Air mutters through the HVAC system and ripples over our skin. Our feet pound against a building's floor, and our hands grasp its railings and knobs. Our daily routines—cooking, cleaning, smoking, bathing—produce an embedded brew of smells that make interiors memorable. Windows puncture walls and expand space.

Hansel Bauman, author of "DeafSpace," notes that people who are deaf or hard of hearing use reflective surfaces to see what is happening behind them. Reflections duplicate space, creating visual echoes.

Sensory design celebrates the qualities of place. Graphic designer Kate McLean created a sensory map of Singapore using experiential data generated by over two hundred residents who went with her on "smellwalks." Suspended in the humid air of this island city are the smells of curry, jasmine, and Manila rope. Little India and Kampong Glam are districts especially dense with scent. McLean's map locates distinctive smells and visualizes their trajectories. Smell cannot be abstracted from bodily experience: "Using humans as sensors is a method that aggregates personal insight…. It is about the acceptance of the subjective as worthy and useful data."[9]

A city is mapped with tiny colored dots.

SCENTSCAPE 06. 2015 – CITY OF SINGAPORE (detail), 2015; Kate McLean (British, b. 1965); 118.9 × 84.1 cm (46 13/16 × 33 7/64 in.); Courtesy of Kate McLean



Designers often find themselves at odds with the body. Modernism tended to favor hygiene and control over organic processes. Beatriz Colomina and Mark Wigley chronicle the war between cool abstraction and the hot messy senses in their book *Are We Human?* Modern design served as an optical painkiller, an anesthetic that dulled the body by massaging the eye. Our modern obsession with smooth, slippery objects arose alongside the drugs invented to blunt pain in the age of modern medicine.[10] Whether banning ornament from architecture or barring friction from interfaces, designers often aim to make people feel less, not more. Don't worry. Be happy. Teflon will calm your nerves and smooth your edges.

Body-numbing visuals saturate design culture. News feeds serve up glossy images of products and buildings that most readers will never meet up close. Museums embalm artifacts in climate-controlled pods of glass and plastic.[11] Design students learn to worship visual form and abstain from touching, smelling, and tasting. Vision crowds out the other senses. Looking trumps making. Digital artists Wang & Söderström create strange still lives populated with glistening, hyperreal artifacts simulated with digital tools.

A still life contains objects with no clear function, such as a block of composite stone, a dollop of orange sponge, metallic teardrops, a pale purple blob resembling coral or a brain.

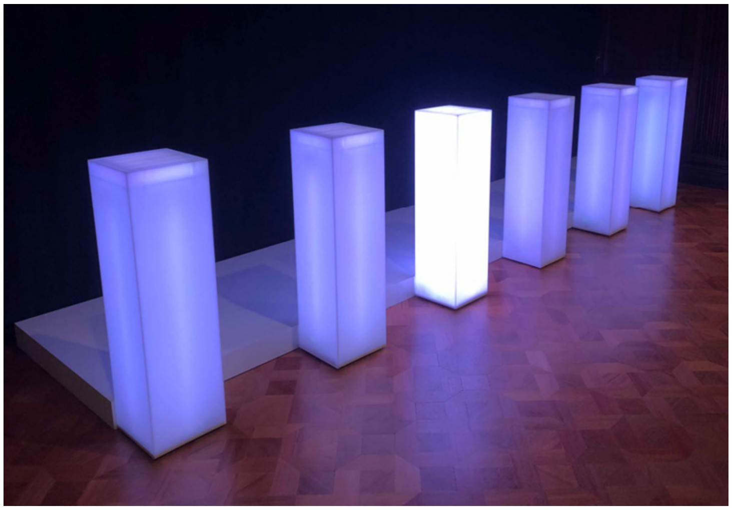
TREASURES 3, 2016; Anny Wang (Swedish, b. 1990) and Tim Söderström (Swedish, b. 1988), Wang & Söderström (Copenhagen, Denmark, founded 2016); 3D software: 3Ds Max, Vray, Modo; Courtesy of Wang & Söderström

Touch borders on all the senses. Skin, the body's largest organ, flows from the outside in at every port of entry: ears, eyes, nose, mouth, anus, and genitals.[12] The mouth and tongue embrace the chewy heat of charred meat or the buttery chill of ice cream. Filmmaker David McDouggal writes, "I can touch with my eyes because my experience of surfaces involves both touching and seeing."[13] The eye strokes the contours of distant glistening bodies the hand can't reach.

Sensory design confronts the body. Designer Jinhyun Jeon's wooden dinner spoon embraces sensory knowing. Our hands measure the object's weight and length. Our skin registers the material's temperature and smoothness. Our fingers navigate changes in form, finding nuance in the bumps along the spoon's edge and at the handle's tip. Our ears prick at the muted clank when the spoon is placed on a tabletop. Our nose picks up the faint glow of lightly stained maple. Objects gain meaning and value in our embodied experience of them.

A spoon is carved from pale wood. A row of bumps line the edge of the bowl of the spoon.

TSS II SPOON, FROM THE SENSORY DINNER SPOON COLLECTION, 2016; Jinhyun Jeon (South Korean, b. 1981), Studio Jinhyun Jeon (Eindhoven, Netherlands, founded 2012); Maple; 2.5 x 2.6 x 13.2 cm (1 x 1 x 5 3/16 in.); Courtesy of Jinhyun Jeon



Six white, glowing, plexi pillars arranged in a semi-circle. Text is engraved on the top surface.

DIALECT FOR A NEW ERA, INSTALLATION, 2017; Artistic Concept and Interface Design: Frederik Duerinck (Dutch, b. 1976) and Marcel Van Brakel (Dutch, b. 1970), Polymorf (founded Netherlands, 2003); Perfumer: Laurent Le Guernec (IFF); Scientist: Asifa Majid; Creative Direction: Jean-Christophe Legreves and Anahita Mekanik (IFF); Scientific Advisor: Sissel Tolaas; Plexiglass, metal interior, LED lighting, scent diffusion; Courtesy of IFF

Sensory design has the power to forge new languages. In 2017 and 2018, IFF (International Flavors & Fragrances Inc.) partnered with Dutch design collective Polymorf to explore the role of scent in human interaction. They collaborated with Professor of Language, Culture, and Cognition Asifa Majid and senior perfumer Laurent Le Guernec to imagine an “invisible dictionary” of nuanced emotional states reflecting the complexity of modern life. Inspired by Majid’s research with indigenous communities such as the Jahai, who have developed an elaborate smell vocabulary, the project presents such uniquely contemorary emotional states as “a moment of collective *déjà vu*,” “the torment caused by the inability to act,” and “being perfectly entangled with another.” Le Guernec composed original scents using IFF-designed molecules to represent the feelings on display. Rather than offer literal or figurative depictions of these emotions, Le Guernec’s olfactory creations are abstract and sensorial—like language itself. In the installation, a series of translucent pedestals are softly lit from within. When activated by a visitor, each pillar diffuses a scent through a line of laser-cut text. Visitors, by connecting each named emotion with a special smell, begin to assimilate a new dialect.

Sensory design rubs up against the living-thingness of the world. A room is not just a cube punctured with windows and doors. It is a sensing creature with deep pockets and velvet shadows. It curves like an eyeball and bends like an elbow. The wool canyons of a blanket trap warmth. The folds of a curtain seize light and sound. A rug inhales noise; floorboards sigh with grief. Sensory design tweaks our skin, bones, and muscles. It tickles, pinches, and pops. It plays rough. It touches us, and we touch back.

Designing LIVE: A New Medium for the Senses

Bruce Mau

We have allowed two of our sensory domains —sight and sound — to dominate our design imagination. In fact, when it comes to the culture of architecture and design, we create and produce almost exclusively for one sense —the visual.

Most design is caged by the image. We “look” at design, we don’t “feel,” “experience,” or “sense” it. In fact, most design is non-sense design—cold, technical, formal, and inhuman—engineered to serve business or technical functions rather than to surprise, inspire, and delight. Such examples include products that work in the computer program where they were developed, but fail in real life; environments that look good in renderings, but are soulless to live in; processes that make sense in theory, but not in practice. So much of our daily experience is an assault on our senses. Our senses are forced to serve as the interface for unrelenting friction and conflict instead of the pathway to inspiration, coherence, and beauty. We are designing the invention of a new medium — the medium of LIVE — all senses design. Like the early days of photography or television, there is no road map, there are no standard formats, there is no existing methodology for the medium of LIVE. We need to explore, experiment, and invent new formats and combinations of sensory experience, new ways of telling stories. We need to design the LIVE design process to open the medium for full immersive experience.

LIVE experience has the bandwidth of reality — it is fully immersive, and the visitor’s body and mind are alive and available for full engagement of all the senses. (Notice we do not use the term “viewer,” which would only reinforce our existing cultural bias.)

However, designers do not have an established creative process for the integration and synthesis of design for all the senses. Our design practice is built for the image. If we are to develop an all-senses design method, we will need to consciously focus on the senses and build a process of synthesis.

To design for all the senses: start with a blindfold.

Begin the work from something other than the visual. The visual so dominates our imagination that we need to shut it down to allow our brain to explore other channels and possibilities. Composer John Cage made a work of silence to help us hear that everything we do is music. We have only one center of attention. The blindfold helps us to focus and move it around to our other senses.

Design the feeling of the idea.

Neuroscience tells us that we are emotional decision makers, not rational spreadsheets. Most of our decisions are made live — in real time without our awareness. Use the language of passion to translate the intellectual into the emotional. Crying is a measuring stick for the quality of your work.

Focus on the visitors' experience, not our message.

We take responsibility for the delivery of the visitors' experience — the story, the tone, the feeling, the cadence, the beginning, middle, and end, the nuance — everything. Our responsibility is not to deliver our message — it is to inspire their feeling, to experience something they have never felt and thought before.

Orchestration is the big idea, the challenge, and the practice.

The greatest value of design thinking and the culture of architecture is the capacity for complex synthesis. The great challenge of our time is synthesis — coherence, intelligence, clarity, beauty. Not discrete solutions to isolated problems, but systematic design ecologies. The ability to understand and synthesize complex, diverse inputs across many disciplines into one compelling, immersive experience is the magic and meaning of design. It is also the underlying method of designing LIVE.

"What is for the eye must not duplicate what is for the ear." — *Robert Bresson, filmmaker*

Every sense experience produces expectation in the other senses. If it looks cold we expect it to feel cold. Our work lies in the play between the senses. In conventional media we see what we hear. We hear what we see. We do what we are told. Open the space between the senses to inspire freedom and imagination and demonstrate the power of human creativity.

Design for each of the senses then synthesize.

Our work is the orchestration of LIVE experience, not a singular image or object. Design the experience for each of the senses independently before you synthesize. Think of each sense as a track in a complex polyphonic composition. You control the mixing board, moving the focus and designing the overlap and interaction of sensory experience for maximum emotional impact.

Design for our sense of time.

LIVE immersive experience happens in time. We know we are alive because we experience time. Therefore, our work is not a fixed object or space. It is a controlled release of ideas and information over time. It is a dramatic experience that evolves and builds in the mind of the visitor. Time is a plastic dimension. We can stretch it or compress it. Think theater, opera, performance art, and happenings. Use storyboards (or whatever it takes) to understand and design the time.

Design for our sense of touch.

Touch is our first language, the first sense that we acquire. Touch is our silent interface with the material world. Touch is the third dimension of surface that speaks to our emotions. Unconsciously, touch tells us whether to trust, whether to pull away or lean in and embrace. Think about how much time Apple spends getting the texture, the touch of every product just right. We know from neuroscience that human touch changes our experience in profound ways. We open up, cooperate more, and feel more connected when we are touched.

Design for our sense of movement.

Our visitors are not static points of view. They are alive and mobile, constantly shifting, exploring, and discovering. Design for discovery and allow them to participate in the story. They move at different speeds. Design for a range of engagement that is the reality of LIVE. Design something brilliant for the visitor who is not going to give you the time of day, and design a reward for those who are inspired and want to go deep into your world. In the words of architect Morris Lapidus, “More is never enough.”

Design sound for emotional impact.

Turn the sound off on any Hollywood film and it will be immediately evident how powerfully the sound colors our emotional experience. Sound can trigger fear and violent response or gentle intimacy. It can draw us together into joyful collective expression, or provide spiritual solace and respite. Most experience is noise, not music. Noise is chaos. Music is design. Remember, everything we do is music — once again, John Cage — or at least has the potential for music.

Design for our sense of taste.

Food is a deep and defining part of our culture. At every major experience of our lives — birthdays, weddings, anniversaries, accomplishments, and transitions — food plays a central role in bringing us together for our celebrations and sacraments. Whenever we spend extended periods of time together, food and drink will be part of sustaining our energy and our ability to focus and participate. Design the potential for taste to be an inspirational social experience, to draw people together to learn and share.

Design for our sense of smell.

The sense of smell is only a few synapses away from the brain. Smell is the most direct pathway to memory. That is why we can remember smells four times more accurately than images, and for a much longer time. We respond to smell in the most visceral way — directly, unconsciously, like the animals that we are. Designing scents is as much art as science and can be profoundly powerful in its emotional impact. Remember that we become "nose blind" very quickly, so part of designing for our sense of smell is creating a way to refresh our ability to wake up and smell the roses.

Design for our sense of connection.

The more digital and distant our world becomes, the more we crave a sense of meaningful connection. This is the power of LIVE. Designing for our sense of social contact, allowing for human connection and the serendipity that happens when we experience one another, is perhaps the greatest opportunity and beauty of LIVE experience.

Design for synesthesia.

Color changes what we feel. Sound transforms what we see. Smell determines what we taste. Synesthesia — the experience of one sense evoking another — is more common than we realize. To design for LIVE we need to design the overlaps and intersections of the senses.

Design for the intersection of digital and physical.

The future of the new medium of LIVE is the synthesis of digital and physical. Every year, new digital technologies change what is possible and transform the expectations of our audience. Visitors arrive with new possibilities and ways of engaging in stories and ideas, and those technologies change their ambitions and expectations.

Finally, open your eyes and compete with beauty.

Nothing moves us more than beauty. We move to the light of genius and joy. We fall in love with it. We pay more for it. We will not win without it. No matter how smart your LIVE design solution, without beauty it will fail. Use all the formal dimensions of design — color, contrast, proportion, texture, image, material —to compete with beauty and win. Extend the idea of beauty beyond the visual to all the senses to fully master the design of LIVE.

The Inclusive Museum

Sina Bahram

My first memory of visiting a museum is from elementary school. I remember trooping onto a bus full of children and the two-hour ride to the museum. When we arrived, I was separated from the rest of the kids and placed in the charge of an older gentleman. He gave me a pair of headphones and a cassette player with an audio tour of the museum on tape.

The reason for this special treatment was because I am blind. Though I have some light perception, it is not enough to appreciate museum exhibits from a purely visual point of view. The kind man spent several hours walking me through the museum, letting me touch things that most visitors weren't allowed to. He found exhibits with audio, olfactory, or tactile components (though more often he was forced to simply verbally describe something that I could not touch or interact with). All the while, he answered — or tried to answer — each and every one of the unending questions that were a hallmark of my childhood. This was a school trip that I'll never forget.

It is important for us to ask why this experience was necessary. Why couldn't I participate with my nondisabled peers? Why were the museum's exhibits and other activities not designed with inclusion and accessibility in mind? After all, museums have made their physical spaces accessible for decades with automatic door openers, ramps, and other affordances for those with mobility impairments. Yet there seems to be a collective failure to recognize that the job is not complete just because those with disabilities can enter the building. Once inside a museum, disabled visitors often find that the level of effort, resources, consideration, and study dedicated to providing equal access for all visitors is disappointingly low.

Attempting to answer the above questions, as well as improve this situation for future generations, drives the work that I do. As an adult, I became a computer scientist with a strong passion for using technology as an equalizer. Today, I have the amazing job of working and playing with museums daily. I started a company, Prime Access Consulting, to help museums make their digital interactives, websites, mobile apps, exhibits, and environments accessible to and inclusive of the widest possible audience. One of the primary philosophies that we bring to this work is that of universal design, sometimes called inclusive design.

Universal design is the act of considering all audiences, or as many as we can, at the beginning of a project, and iterating upon this consideration until we arrive at a solution that is usable by far more people than if we had not taken such a design tact. “Inclusive design” is a newer term, used by many contemporary designers and advocates. While “universal” implies a potentially unattainable burden for designers and developers, “inclusive” is an invitation. It’s warm, and it aligns with most people’s basic values. We include our friends, our loved ones, and so on. Inclusive design recognizes that people have multiple forms of identity and difference, including age, ability, language fluency, socioeconomic status, and cultural background. Accounting for those differences doesn’t mean making everyone the same.

Whichever term you prefer, universal design and inclusive design address the big picture. Accessibility, on the other hand, consists of those things we do specifically for those with functional differences. Consider an automatic door opener. We may think it to be a pure accessibility accommodation because it is for those with mobility impairments, yet anyone can use it, from those with a temporary sore leg to someone carrying packages in both arms, and so on. Alternatively, a sign language tour tends to be more of a pure accessibility accommodation as it is most critical for those with a hearing impairment. If, by now, it seems that there is a lot of overlap between accessibility and inclusive design, even to the point where accessibility may be thought of as a subset of universal design, that is because that's exactly the case. Such a realization is key to understanding the emergent benefits of thinking about all visitors.

This issue of accessibility and including the widest possible audience has been considered not only by the museum community, but by every sector one can imagine. In the design and development of technology, home appliances, consumer goods, and education, just to name a few, universal design has been widely adopted as the strategy that yields the greatest possible accessibility to the highest number of people.

In 1997, the Center for Universal Design at North Carolina State University in Raleigh published seven principles of universal design for buildings, outdoor environments, and products. Each principle inspires me to ask a question that should be considered at the design phase of any digital or physical object with which museum visitors might interact. Let us examine each of these seven principles as well as a museum-inspired question around each. I've shared a few answers that my clients and I have come up with, but these examples are by no means the only right solutions to these critical inquiries. For some of these principles, the example provided does not come directly from the museum world. I use the lack of such an abundance of museum-based examples as a clear reminder of how much work is left to be done.

Figures stand in front of a large digital screen. They are in a museum gallery with furniture, artworks, and educational panels.

PAINTING & SCULPTURE INTERPRETIVE GALLERY; San Francisco Museum of Modern Art; Photo © Belle & Wissell, Co.

1. Equitable Use

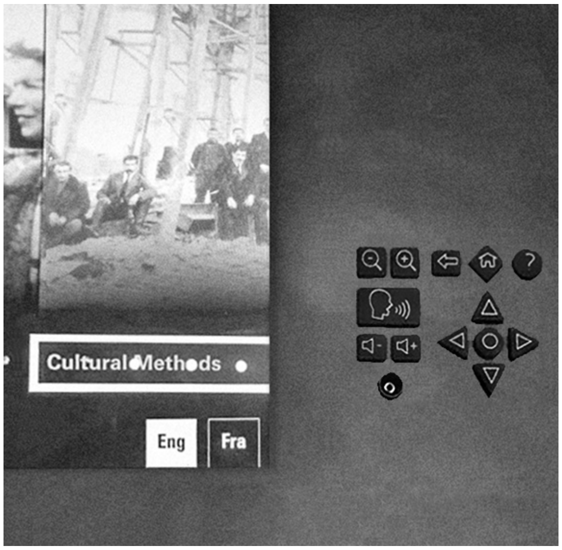
Can visitors with different functional limitations get a similar, or equitable, experience?

In the image, we can see a large multi-person, multi-touch interface composed of three vertical touch screens put side-to-side to form a touchable wall of art in the San Francisco Museum of Modern Art. It is easy to write off an experience so rooted in the visual as inaccessible — even uninteresting or inappropriate—for a blind or low-vision audience. Yet this wall of art has a braille and large-print label inviting visitors to plug headphones into it and to activate an accessibility button. Upon being pressed, the accessibility button toggles on a voice layer that walks the user through the experience. The images of art on-screen are all beautifully described.

The videos have audio description and captioning, and any text is enlarged. The gestures to control this interface have been specifically influenced by the industry-leading solution for touch-screen accessibility for the blind, Apple's iPhone. This touch-based digital exploration of modern art requires only the use of a single finger to be fully controlled, thus allowing those with reduced dexterity to participate. By gliding a finger across the screen, a vision-impaired visitor can explore the artworks on display, listen to their visual descriptions, interact with multimedia such as videos, and in short, enjoy the same experience as their sighted peers.

2. Flexibility in Use

Can visitors interact with the information in a variety of different ways?



Next to a digital screen are physical buttons with tactile symbols indicating forward, back, zoom in, zoom out, sound, volumne, and cursor movement.

DIGITAL INTERACTIVE; Canadian Museum for Human Rights; © CMHR / Ian McCausland

If we think of visitors who cannot see or hear perfectly, the ideas of multimedia-based content, digital text being displayed, or a touch-screen interactive may appear to be quite problematic, but they do not have to be! In the image below, we see a photo of one of many digital interactives at the Canadian Museum for Human Rights. This interactive is one of dozens at the museum equipped with a universal keypad, speech output, captioning, tactilely differentiable buttons, and many other design considerations. The digital interactive is usable by someone who is blind or low vision, deaf or hard of hearing, or has trouble performing complex physical gestures — and to a myriad of individuals that have limitations we cannot, nor try to, predict.

The universal keypad with its rubberized large buttons and clear markings is not the only solution for making such interactives accessible. Other approaches such as that from SFMoMA, discussed previously, allow for making the touch screen natively accessible without a keypad. This diversity of choice is essential to devising inclusively designed experiences. There is no one-size-fits-all solution in any technical field. Inclusive design is no exception.

Turning our attention to a non-technology approach, the Museum of Contemporary Art in Chicago recently held a relaxed performance for one of its public events. This performance allowed those with autism, those who have trouble sitting for a long time, those who may not be comfortable sitting in the dark, and many others to enjoy a show, but with some drastically relaxed expectations around audience behavior. As is the case with so many of these examples, while those with disabilities may have been the impetus of such an approach, it proved helpful to so many more visitors. For example, think of a woman who is pregnant and needs more frequent restroom breaks, or a family attending with babies or very young children.

Holding a relaxed performance is not the only way of including those with sensory impairments. Some museums, for example, periodically open their institution an hour earlier to invite those on the spectrum or anyone with a sensory sensitivity to crowds and loud noises to enjoy the museum in a more peaceful way.

3. Simple and Intuitive Use

Can visitors with different experiences or knowledge benefit from the information being presented?

In this image, we can see a bathroom sign that indicates gender in multiple languages. In English, it says "Women." In Spanish, it says "Mujeres." The information is also presented by way of a pictogram and replicated in braille.

This redundant display of information is helpful to a wide variety of visitors. Persons with disabilities, those who speak a different language, and visitors who are native speakers can all utilize this inclusive sign. Furthermore, there are overlaps in terms of the pictogram's audience. Yes, the pictogram is critical for someone who does not read English or Spanish, but it is also helpful to those with a reading disability, children, and other individuals who may simply be in a hurry.

4. Perceptible Information

Can visitors access and interact with the information being presented, independent of a sensory disability and disturbances in the environment?

If we are to be pedantic, there are really two questions embedded in this principle. The first deals with equal access despite a sensory disability; the second revolves around disturbances in the environment.

Let's take the second query first: disturbances in the environment. For acoustic disturbances, such as crowd noise or distracting sounds from surrounding exhibits, a simple volume knob can work wonders. Such a knob allows visitors to turn up the volume of any audio if the surrounding environment is noisy, but it can also facilitate augmented volume for deaf or hard-of-hearing visitors and lower volume for those with audio sensitivities. Again, simply giving users a choice and control over the way they wish to consume the information being presented massively elevates their experience.

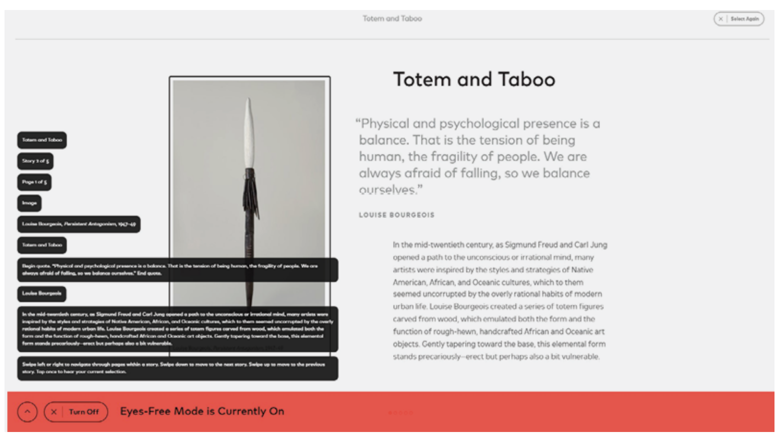
Turning our attention to the first query, consider information taken from the Coyote system. Coyote is an online platform that streamlines the creation and distribution of visual descriptions. Originally a project that my firm developed with the Museum of Contemporary Art in Chicago, it is now being used by multiple institutions to drastically revolutionize the pipeline that institutions, and individuals, use to create and convey the visual description of art. At the core of Coyote is the belief that visual description is not throwaway copy. It is a content-creation task deserving of a mature workflow. Such a workflow tool was absent, and so we invented Coyote to fill this deep unresolved need. Coyote also expanded the premise of visual description, especially around images on the web: for instance, rather than having one official description for a given image, in Coyote multiple descriptions can exist for a single visual object. In fact, these descriptions can be of different forms, some short and some long, and in different languages. We do this because of our fundamental thesis that no single description is most appropriate, or correct, for any given object. Instead, we strive for a multiplicity of voices. Much like everything else in inclusive design, this way of thinking and implementing not only helps persons with disabilities but has many other far-reaching benefits. One such benefit is to return agency back to the visitor at an art museum. By surfacing these visual descriptions for everyone, not just those who have trouble seeing, Coyote allows visitors to feel okay consuming information about what is visually going on, instead of promulgating that unfortunately common experience within an art museum that leaves visitors asking, "What am I looking at, and why is it important?"

5. Tolerance for Error

Can visitors always return to a consistent, known starting point so that, for example, they don't cause systems to crash or behave unexpectedly, regardless of the actions they take?

Museums generally do a good job with this concept. We are used to having digital interactives that always return to a known starting point upon request or after a time-out. Almost all digital interactives follow a firm rule that software should fail gracefully and quietly in visitor-facing interfaces. But what happens when there is an accessibility mode that can be toggled on or off?

An accessibility mode may be available, which changes the way an interactive exhibit behaves. Perhaps it simplifies the gestures that can be used, allows for a keypad instead of a touch screen, or enlarges text. If such a feature is available, then we must be sure to make clear how to turn such a mode off for visitors who may not require such an interface.



In this image from the Painting and Sculpture Interpretive Galleries Table Experience at San Fransisco Museum of Modern Art, we can see the on-screen prompt notifying users that an accessibility mode is on and how to turn it off. This message serves two purposes. It allows visitors to turn off a feature that they do not need, and it notifies anyone able to see the message of the availability of such features in the first place. It is important to keep in mind that accessibility features should not be hidden away, but instead embraced and advertised. We should be proud of the increased number of people we are trying to welcome into our institutions.

6. Low Physical Effort

Can visitors fully appreciate the given information without needing much physical effort or dexterity?

A small girl walks up a ramp with dual handrails.

CANADIAN MUSEUM FOR HUMAN RIGHTS; © CMHR / Ian McCausland

In this image, we see a beautiful ramp at the aforementioned Canadian Museum for Human Rights. Notice that the handrails on this ramp are placed in two positions, one several inches lower than the other. This thoughtful design decision has many implications. It can assist wheelchair users, children walking with their parents, or individuals of small stature. Speaking of wheelchair users, the ramp, combined with elevators, is obviously a critical affordance for making the museum physically accessible, but it is hardly for wheelchair users alone. By adopting this ramp as a central mechanism of traveling between floors, the museum achieves better audience flows (no crowded stairwells), makes it easy for those with roller bags or other wheeled accessories, allows large groups to travel together more easily (critical for the school groups that frequent the museum), removes the social awkwardness of one member of the party splitting off to use an elevator, and allows visitors to enjoy a beautiful journey through the building's unique architecture.

7. Size and Space for Approach and Use

Can visitors get close to the exhibit, have enough space in which to move around—even with a wheelchair, walker, or crutches—and manipulate it, independent of posture or other physical limitations?

In this image, Sina Bahram touches tactile, 3D replicas of Andy Warhol's work at the Andy Warhol Museum. These have been placed on tables such that a wheelchair user can approach from three different sides. Some of the replicas (not visible here) are also on turntables so that one can turn the object being felt instead of turning one's own body. The important takeaway here is that we should not model our visitors as just one persona. Most of the time, a person is not only blind or only a wheelchair user, but has multiple functional differences from their fellow visitors. Sometimes, these functional differences are temporary, such as a broken arm or forgetting one's glasses. By building up our approach in layers, and considering the experience holistically, we can strive for the most inclusively designed experience possible. Photo by Pamela Horn.

Conclusion

Social inclusion and interaction are among the many benefits of following universal design. While I greatly enjoyed my first museum experience as a child, I wished that I could have interacted more with my classmates, felt part of the group, and been able to participate in the same activities. This element of inclusion should be a central motivating factor when designing exhibits. Inclusive design facilitates this social inclusion and interaction among visitors by allowing us all to interact with and enjoy the offerings of an institution together and in similar ways, instead of providing a well-meaning but still isolating experience.

We will not get these solutions 100 percent correct the first, second, or tenth time, but we cannot allow fear of the lack of perfection to continue being used as a justification for doing very little. Inclusion is not a binary pursuit with a finite destination. Inclusion is a state of thinking and acting toward a shared purpose based on a commitment to iteration, refinement, and self-improvement.

Reflecting further upon my museum experience as a young child, I am reminded of the words of American author and poet Maya Angelou, “I’ve learned that people will forget what you said, people will forget what you did, but people will never forget how you made them feel.” Exhibits following universal design principles can facilitate a powerful feeling of inspiration, awe, wonder, and excitement for all visitors, not just those who meet an idealized persona. More important, following such best practices can help prevent many visitors from feeling excluded, unwelcome, or ignored — something that has been true for far too long. I hope that you, dear reader, will join me and my colleagues in our journey to make all users feel welcome and accepted

A full-color tactile map shows streets, buildings, and parks in Washington, DC. The map is labeled in braille and visible text. Map details are printed in raised ink.

TACTILE MAP, NATIONAL MALL, SMITHSONIAN INSTITUTION (DETAIL), 2017; Steven Landau (American, b. 1960), Touch Graphics (Elkton, Maryland, USA, founded 1997); Digital print with ink and raised graphics. This tactile map is designed to be beautiful and useful to many people, including those who are sighted, blind, and low vision.

Notes on Touch, Sound, Smell, and Flavor

Ellen Lupton | Adam Jasper & Nadia Wagner

What are the senses and what are they for? The senses assemble reality from vibrant morsels of stimulation—odor molecules meet the mucous membrane, light falls upon the retina, vibrations pulse against the eardrum. The senses are protective mechanisms. A foul smell, a bitter taste, or a rustling in the grass is a sign of danger, making our hairs raise, our throats clench, our muscles tense, our eyes dilate, or our body odor turn sour. The senses deliver joy as well as warnings, lighting up the body from head to toe and from inside out. From the tang of strawberries to the crinkle of satin, beauty arrives in a rush of light, warmth, texture, and vibration.

TOUCH | Ellen Lupton

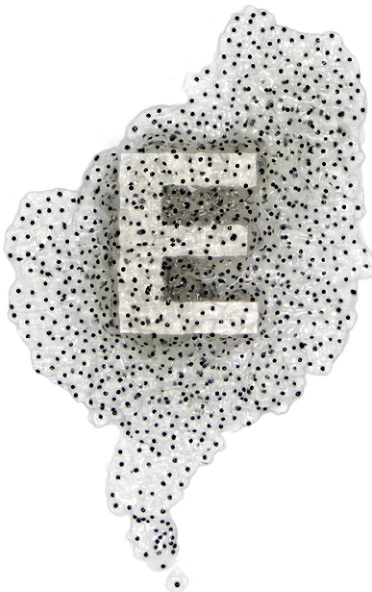
Touch delivers full-bodied impressions of places and things. Touch penetrates the body. It brings pain and pleasure, warnings and delight. It can calm us, alarm us, connect us, and overwhelm us. Our hands and fingers wield stones and sticks, slings and arrows, brushes and pens. Our feet and limbs scuttle up rocky paths and blunder down slithery slopes. Our tongues probe hot gobs of oatmeal and the polished underbelly of a spoon. Our bodies feel the weight of a wool blanket, a rough embrace, or a hot day in August.

Touch is specialized

Skin, the main instrument of touch, is more than an exterior envelope. This varied surface — thick or thin, hairy or smooth — wraps inside the mouth, nose, ears, and genitalia. The receptors in our fingertips gather hyper-detailed data about the things we touch, while other regions of the skin convey impressions in lower resolution.[1] Try studying the face of a coin first with your index finger and then with your elbow. Was that heads or tails? Your elbow will never know. The edges of coins are designed to be legible to the fingertips. Reach into a purse or pocket and see if you can tell a dime from a nickel by its size, thickness, and patterned edges.

Touch is layered

A chunk of wood or a blob of silicone delivers tangled impressions of temperature, texture, pressure, and resistance. What is the feeling of wetness? Splash some water on your face. Wetness is a “touch blend” that includes the coolness of evaporation and the weight or pressure of the moisture on your skin.[2] Intellectually, one can pick apart the ingredients that make up how something feels, but the embodied brain swirls those elements together into a unified perceptual Gestalt.



The letter E is submerged in a transparent ma of frog eggs.

FROGSPAWN TYPOGRAPHY, 2014; Monique Goossens (Dutch, b. 1971); Courtesy of Monique Goossens

Touch is social

From a pat on the arm to a slap on the face, touch communicates love, trust, or dominance. All people crave touch. Infants deprived of touch fail to thrive. Care facilities for the elderly have begun to employ robotic pets — known as “socially assistive robots” — to satisfy this need for living contact by way of artificial beings.[3] Equipped with digital sensors and a purring heart, these uncanny creatures respond to touch. Stroke the kitty’s head and it nuzzles against your hand; pet the back of its head until it rolls over for a belly rub and eventually falls asleep.

People who are deaf-blind communicate through touch-based processes, from finger spelling to exploring objects with their hands or feet. Diagramming the elements of a room on the back of a deaf-blind person’s hand helps them picture the environment. Some people who are deaf-blind use a grammar of touch that includes pressure, location, speed, hand shape, and motion. For example, a gesture’s pressure can be firm or light, while moving in circles or taps. Expressing the sign for “yes” with increased speed and pressure makes the message more emphatic (“Oh, yes!”).[4]

Touch is spatial

Proprioception is the awareness of a body's location, posture, and movement, enabled by receptors distributed throughout the skin, muscles, tendons, and joints. Vision and hearing further contribute to this sense of movement and orientation. Try touching your nose. The ability to instinctively move your arm, hand, and fingertip to this exact, invisible location requires an integrated understanding of the body's parts and motions. Now, try picturing each joint in your body—from knees and elbows down to each segment of each finger or toe. This act of focusing on the skeleton's areas of articulation creates a fleeting geometric schema of your posture in space—a fragile constellation of points. Environmental psychologist James J. Gibson calls this awareness "subjective skeletal space."[5]

Touch is active

When your soft body bears down against a hard chair (or, if luck will have it, your hard body sinks into a soft chair), you are experiencing passive perception. In contrast, the process of touching your nose or grasping an object requires active perception.

Sitting doesn't need to be passive, however. Chairs designed for active sitting may help people burn energy, build core strength, and feel alert. The Tip Ton chair was designed by Edward Barber and Jay Osgerby for use in schools. Manufactured by Vitra following several years of research, the Tip Ton chair tilts forward on a blade-like base. The forward position, designed for working at a desk, helps users sit with their spines straight rather than slumped. The back-leaning position supports resting during a lecture or break. The ability to change position frequently helps students stay focused during long periods of desk time.[6] The designers considered other sensory factors as well. Lightweight plastic makes Tip Ton chairs easy to stack and move around and also limits noise. According to Barber, "Clattering chairs are a big problem in large numbers."[7]

Active seating can be useful to people with sensory processing disorder (SPD). People with SPD can feel overwhelmed by bright lights, the sound of people eating, or the texture of clothing. Other people with SPD need intense stimulation — physical, auditory, or tactile. Products created for children and adults who are calmed by bodily motion include inflated "wiggle cushions" and therapy balls. Springy surfaces allow users to shift, bounce, and move about while seated. Seats covered with spiky, furry, or bumpy textures offer further stimulation.[8] Compression garments use weights and stretchy fabrics to exert reassuring pressure on the torso.[9]

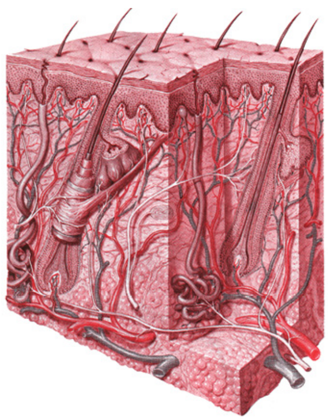
A green, armless, plastic chair is shown from the side. It has a blade-like base that lets it tilt backward and forward.

TIP TON CHAIR, 2011; Edward Barber (British, b. 1969), Jay Osgerby (British, b. 1969), Barber & Osgerby (London, UK, founded 1996), Vitra (Birsfelden, Switzerland, founded 1950); Polypropylene, polyethylene; 78.6 × 50.9 x 55.5 cm (30 15/16 × 20 1/16 × 21 7/8 in.); Photo © Peer Lindgreen

Touch is haptic

When sitting in a chair, you feel pressure against the surface of your skin as well as within your muscles and other tissues. Body-based touch and skin-based touch work together to create haptic perception, defined by Gibson as the system by which the individual "feels an object relative to his body and the body relative to an object." Receptors located in the muscles and the skin relay signals to the brain about feelings of motion, pressure, pain, heat, and resistance. Every human hair — wrapped around its base with nerve fibrils — is a feeler reaching into the environment. Likewise, the fur, horns, and antennae of animals have remote sensing functions. Humans use sticks and other tools to extend the sensory grasp of their limbs. A pencil, paintbrush, or walking stick is an antenna exploring the environment.[10]

The act of pushing a button or swiping a screen engages motion and pressure. Digital buttons and menu bars use drop shadows, beveled edges, translucent layers, and juicy highlights to invite action from users. Interaction designer Josh Clark explains, "We now touch information itself: we stretch, crumple, drag, flick it aside. This illusion of direct interaction changes the way we experience the digital world."[11] Designers use sounds, vibrations, textured surfaces, responsive animations, and gesture-based interactions to make digital interfaces become more physical. Alas, the replacement of tangible controls with seamless touch screens renders many products useless to people with blindness or low vision.



Anatomical drawing shows a layered cut-away of a section of human skin. The base of each hair is wrapped with nerve fibrils.

Touch is visceral

We feel with our skin, our limbs, and our inner organs. Dwelling deep within the gut are sense receptors that regulate appetite and digestion, alerting the brain when the stomach is stretched and indicating which nutrients need to be broken down and absorbed.[12] These nutrient-based receptors are similar to taste buds — responding to chemicals in food — but are distributed beyond the reach of consciousness. Gut-level sensors also respond to danger and desire. In her book *The Tactile Eye*, film critic Jennifer M. Barker explains that a "gut response" or a "visceral reaction" jolts the body at its core. When sex or violence portrayed on screen stirs desire or make us recoil in shock or revulsion, we are responding physically to what we see and hear.[13]

Monique Goossens, a graphic artist from the Netherlands, has created letterforms from hairnets, strands of hair, and clumps of frog eggs. Meticulously photographed and printed, her images are both elegant and alarming, provoking feelings of disgust as well as awe and fascination.

Touch is emotional

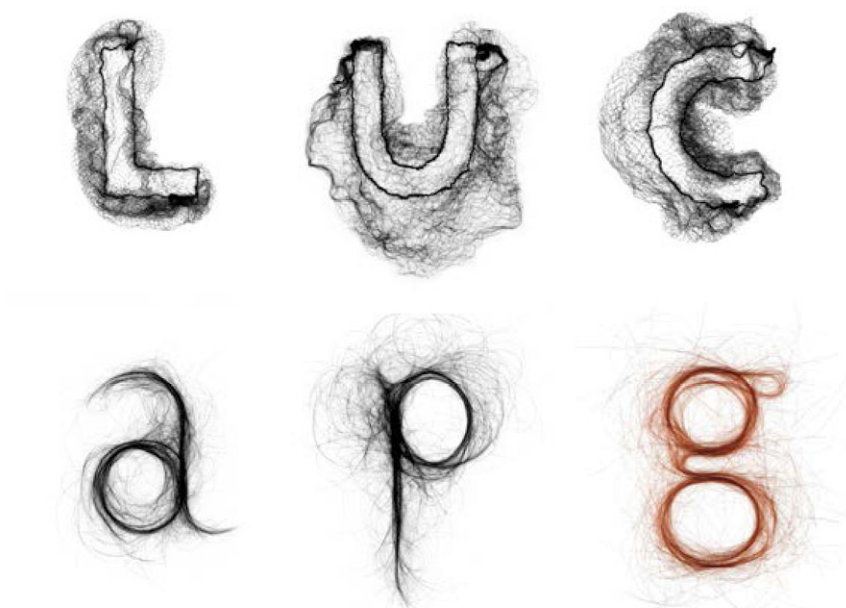
In a well-known study, participants encounter a researcher in a hallway on their way to the session. This investigator, who happens to be carrying a stack of papers and a drink, stops and asks the participant to briefly hold the beverage cup. (Unknown to the human subject, this cup is a star player in the study.) In some instances the cup is warm, and in others it is cold. Soon after, subjects are asked to evaluate a job candidate. Subjects who had been holding the warm drink tend to feel more favorably toward the candidate than those who had held the cold one. Physical warmth translates into positive emotions.[14]

Touch is visual

The eye is a surrogate for the skin. We can look at things and see if they are sticky or slick, nubby or smooth, sharp or blunt, before we ever touch them. Glance around and find a surface that looks soft — a cushion or a drape, a dog or a cat, or the pattern printed on this page. Scientists describe softness as the "compliance" of a surface, its ability to deform in response to pressure. Surface compliance is often visible. We see softness. We notice how a surface behaves when it's prodded or poked. The nubby grain of a fleece jacket and the dullness of a rubber tire help us predict how a surface will feel and behave.[15] We hear softness, too — a wineglass or a murder weapon won't smash or clatter when it falls upon a thick carpet. Designer Petra Blaisse is known for creating large-scale curtains that move and breathe across the expanse of a stage or an architectural facade. Blaisse's Touch series of wallcoverings (commissioned by Wolf-Gordon) feature detailed photographs of wool, felt, fur, and knitted or woven fabrics. Printed at large scale, each wallcovering appears soft and fuzzy, even though it's flat.

Pink wallpaper is printed with an enlarged, high-resolution photograph of fuzzy twine.

SIDEWALL, CORD #1, 2013; Petra Blaisse (British, b. 1955); Made by Wolf-Gordon Inc. (New York, New York, USA, founded 1967); Rotogravure-printed on vinyl; 293.4 x 137.2 cm (9 ft. 7 1/2 in. × 54 in.); Collection of Cooper Hewitt, Smithsonian Design Museum, Gift of Wolf-Gordon, 2004-26-1; Photo by Matt Flynn © Smithsonian Institution



Hair nets cloak the letters L, U, and C.

Strands of hair clump together to form a, p, and g.

NET TYPOGRAPHY, 2013; HAIR TYPOGRAPHY, 2013; Monique Goossens (Dutch, b. 1971); Courtesy of Monique Goossens

Touch unites the senses

Visible textures add depth to printed pages and flickering screens. Sounds and colors that seem warm or cool, dull or sharp change the emotional valence of a product or place. Well-shaped tools feel good in the hand. Textured surfaces enhance the sound of a room. Objects designed for touch enable people with impaired vision to use everything from kitchen tools and bathroom faucets to books, maps, and currency. Designing for touch creates a humane and inclusive world.

SOUND | *Ellen Lupton*

Every sound originates in a disturbance. A glass shatters, a shoe falls, a bell tolls. The disturbance makes molecules bounce against other molecules. This chain of motion takes the form of a wave, spreading outward from the initial disturbance in a pulsing pattern of alternating compression and decompression. The wave moves through air, water, wood, and glass, through flesh and bone, through earth and rock. When the wave causes mechanisms inside the ear of a human or other creature to vibrate, the brain processes the wave as sound.[1]

Sound is not the same as hearing

Hearing happens when sound waves cause a creature's eardrums to vibrate, passing signals to the auditory nerve and the brain. Hearing aids are designed to amplify sound waves. Cochlear implants, also created for people with damaged hearing, turn sound waves into electrical impulses that stimulate the auditory nerve; the brain interprets these signals as sound. Mastering this process takes time and isn't successful or desirable for all people. Hearing is not the only way to experience sound. At a concert, drums beat against the chest and pulse up through the feet. In a park, wind rattles the trees and cools the skin. On the street, the pavement shakes when a truck rumbles by.

Sound is personal

Individuals have their own hearing ranges, just as people have differences in vision. These differences change over time. People in developed societies routinely correct their vision with eyeglasses and contact lenses, but they are less likely to use hearing aids. Hearing aids are expensive, and some users attach a stigma to them. Others find them uncomfortable, obtrusive, or difficult to use.

The loudness of sound is measured in decibels, and its frequency is measured in Hertz (Hz). A whistle or siren creates high-frequency sound waves, while a drum or truck engine produces waves at a low frequency. Sounds lower than 20Hz are experienced as vibrations. A person's ability to hear soft or loud sounds varies depending on the frequency. Many people can more easily understand words spoken in a low-pitched voice than a high-pitched one.

Sound is haptic

Many digital devices employ interfaces that communicate through tactile vibration and physical movement or resistance. These haptic signals can convey degrees of intensity or they can assign unique patterns to different types of message. A vibration can tap the skin with a precise pattern, or it can blur into an overall texture. Vibrations localized on one part of a touch screen can give users the impression that they are manipulating mechanical controls , not just stroking a glassy surface. Ultrahaptic technologies cause air itself to vibrate and change pressure, creating a tangible illusion of objects and actions.

Designing how a phone or watch vibrates is concurrent with designing how it sounds. Conor O'Sullivan, Sound Design Lead for Google, says, "Haptics and sound are both waveforms, so I treat them together."[2] Vibrations and audible signals combine into a unified experience. Have you ever felt an earthquake? The sound and the vibration merge into a wave of audible motion. When a smartphone rings, the device itself resonates — its materials vibrate to amplify the sound emitted through the speaker. The device interacts with its environment as well. Its vibration sounds different when the phone rattles against a glass tabletop than when it nuzzles into a warm, soft palm.

Sound is spatial

Although sound enters the ears in a single wave, a hearing person walking through a park can make out children laughing, gravel crunching, and engines whirring in the distance. The direction of sound helps listeners untangle these different sources and build a picture of places and events. Just as binocular human vision creates a sense of depth by combining two images (one picture from each eye), binaural hearing creates depth by combining input from the left and right ears. Sitting at a dinner table, a person with normal hearing can tell two voices apart, not only because the sounds have different frequencies but because they have unique locations. It's harder to distinguish the same voices coming from a radio or television. Binaural recording is a technique for creating three-dimensional sound by recording sound with two microphones positioned apart from each other a distance equivalent to a human head. Listeners using headphones or occupying a controlled environment will feel the experience of live sound.[3] Bats and whales use echolocation to find objects and navigate spaces. A hungry bat emits a high-frequency sound (beyond the range of human perception) and hears it bounce off the doomed body of a mosquito. Some blind people use mobility canes to tap and listen for echoes, thus using echolocation to sense walls and doorways. A sonogram uses sound instead of light to see inside the body, creating pictures by bouncing sound waves against hidden structures.

Dutch designer Sanne Gelissen plays with the direction of sound in Sound Scene, a beautifully crafted speaker that directs sound waves to a precise location. Most sound systems are designed to fill a space with music, enveloping the whole room. Gelissen's system uses a concept similar to a flashlight, whose reflective bowl focuses light in a single direction. The speaker in Sound Scene points inward at a large parabolic bowl, which reflects the sound waves back toward the listener at a specific location. The bowl, reminiscent of the horn on a gramophone, is made of glass fiber laminate, a hard surface designed to reflect sound waves. The shape of the bowl targets common mid-tone frequencies. Sound Scene creates an intimate experience that isolates and personalizes sound.

Cities have sonic signatures. Shared_Studios, founded by Amar C. Bakshi in Washington, DC, creates two-way audio/video connections between dozens of cities around the globe, allowing a person in New York or New Haven to speak with someone in Iraq, Rwanda, Mexico, or Detroit. Curators living in these different areas have collected sounds that are unique to these locations.

A woman sits on a chair facing a large amplifying device. A cup-shaped speaker points inward at a larger parabolic bowl, which resembles a horn on a gramophone. A dog watches from the other side of the speaker.

SOUND SCENE, 2016; Sanne Gelissen (Dutch, b. 1988), Sanne Geeft Vorm (Eindhoven, Netherlands, founded 2016); Glass fiber laminate, wood, metal; 110 × 40 × 65 cm (43 5/16 × 15 3/4 × 25 9/16 in.); © Design Academy Eindhoven Photographs. Photo by Femke Rijerman; Courtesy of Sanne Gelissen

Sound is synesthetic

Sound primes us to see. When a dog snarls or brakes screech, images rush to our minds. Filmmakers build suspense with ominous soundtracks. Musicians and audio engineers call a sound "bright" or "dull" depending on its overall frequency. The clash of a cymbal is considered wide and flat, while the voice of a flute is bright and sharp. Such terms assign visual and tactile qualities to sound.[4] People with synesthesia link certain sensations in a consistent or systematic manner — as do people with more ordinary sensory responses. Metaphors such as "piercing cry," "soft whisper," or "coarse language" assign tactile characteristics to sounds.[5]

Researchers in Spain wanted to learn if taste could be associated with qualities of music. They asked a group of jazz musicians to create short improvisations in response to the basic tastes—salty, sour, sweet, and bitter. They analyzed the resulting music and looked for patterns. In response to sourness, the musicians tended to create compositions with short notes that were high pitched and dissonant. In response to a bitter taste (such as coffee or dark chocolate), the musicians tended to create compositions whose notes were slower, lower, and more softly differentiated (*legato*). They found similar correlations for sweet (long, low, and soft) and salty (*staccato*, with quick, sharply separated notes). In a second experiment, the musical pieces were played for ordinary listeners, who then assigned taste labels to each composition. Participants affirmed the inclinations of the musicians to a degree substantially higher than chance.[6]

Sound is energy

Sound always results from an action — a string has been plucked, a rock has been thrown, or a door has been slammed. Many of the words used to describe sounds in English imitate the sounds of actions: *bang, bump, crunch, smash, tap, tinkle, whistle, whomp*. Objects and materials make sounds when they fall, break, or bend, or when they crash into other things. When these actions occur, energy is released as sound.

Sound is communication

Sound and gesture are the wellsprings of language. Humans construct intricate discourse when they speak, and they express emotion when they laugh, scream, or sing. Jin Saito's Lyric Speaker connects sound to words. Saito believes that to fully experience a song, you must grasp its words. He told us, "In Japan we believe that words have souls. People have souls. Dogs and cats have souls, and words have souls. This speaker shows the souls of lyrics. It makes music and lyrics into a whole." The Lyric Speaker downloads a song's lyrics from an online database and generates typographic animations in real time, based on the mood and structure of the music. (An algorithm analyzes the music for its soft/hard and positive/negative characteristics.) For songs with no lyrics, the software generates geometric compositions. The animations vary each time a song plays. Rendered in subtle shades of black and white, motion graphics pulse across the speaker's glass skin. The words and shapes appear on screen in sync with the music.

Two saucer-shaped black amplifiers are attached to a clear glass screen surrounded by a dark frame. On the screen, the text of a song's lyrics are animated.

COTODAMA Lyric Speaker, 2016; Naoki Ono (monom) (Japan, b. 1981) and Lyric Speaker team (Tokyo, Japan, founded 2016); ABS, galvanized steel, acrylic plate; 52 × 14 x 35 cm (20 1/2 × 5 1/2 × 13 3/4 in.); Photo by Hisashi Ootsu

Sound signals danger

Sound alerts humans and other creatures to their environment in 360 degrees. Hearing keeps us tuned in to crying babies and bumps in the night. Paying attention to sound can be a matter of life or death. Alarm fatigue is a problem afflicting hospital wards, air traffic control rooms, and other environments that pelt workers with beeps, buzzes, and sirens. Repeated false alarms and confusing signals breed exhaustion and indifference. Some systems are so annoying, users shut them off completely — with potentially catastrophic effects. An auditory display is a set of sounds representing the state of a system. Sounds in an auditory display might range from a gentle background noise that signals normal functioning to alerts demanding attention and action. A shrill, blaring siren can cause a state of momentary shock, requiring operators to lose valuable response time before regaining their focus. Some sounds function best in the background. The rhythmic whir of a machine could indicate that a system is running normally; a sudden break in the pattern is cause for concern. Effective auditory displays, designed in conjunction with visual and tactile signals, reinforce multisensory information.[7]

Designers and engineers are studying the effects of sound on human behavior. Joel Beckerman and his colleagues at Man Made Music are researching a unified language of auditory alerts for use in hospitals. Although studies show it is difficult for humans to differentiate among more than six different alarm sounds, the average number of alarms in an ICU has increased from six in 1983 to more than forty different alarms in 2011. Beckerman says, “We envision creating a standardized, open-source sonic language that hospitals around the world can use.” Instead of letting each device make its own special blips and beeps, the system will employ a limited and universal sonic vocabulary.[8]

Sound is material

Felt pads keep chair legs from screeching against a hard floor. An oak door clunks solemnly shut, while an aluminum screen door quivers and squeaks. The clatter of glass and tableware in a café spins a bright cloak of ambient sound. The density, elasticity, plasticity, and “squashiness” of a material affect the sounds it makes when it collides with other materials. Sound waves move quickly through matter that has densely packed molecules, such as steel or diamond. Waves are deadened and absorbed by materials like cotton, wool, or foam rubber. LABA, designed by Eason Chow and Pravar Jain, is a series of prototypes for audio speakers that alter sound based on the materials used and the shape of the speakers’ earlike horns. Each horn amplifies and reflects sound in a different way, creating different auditory effects. A glazed ceramic horn maximizes the reflection of sound waves, while a horn lined with wool localizes sound to the zone of the listener. A horn laced with silicone at its periphery amplifies sound and gives it a warm tone.

Four white, cone-shaped speakers, each the size of a large coffee cup, have different textures, ranging from smooth and hard to rough and fuzzy.

LABA SPEAKERS, 2017; Eason Chow (Singaporean, b. 1989) and Pravar Jain (Indian, b. 1993); 3D-printed nylon, wool, ceramic, plastic, electronics; Each: 14 x 11 x 11 cm (5 1/2 × 4 11/32 × 4 11/32 in.); Courtesy of Eason Chow

Sound is experience

Designers create interfaces that shiver and ping to communicate actions. Architecture shapes sound — and sound shapes architecture. A tree falls in a forest. From the point of view of physics, it doesn't matter if the forest is empty when the proverbial tree hits the ground. Molecules bang back and forth against one another with or without a live audience. From the perspective of psychology, however, it matters very much if sensing creatures occupy the forest when those leaves shiver and those branches snap.

Designers engage with the lived, bodily phenomenon of sound. Fabrics, rugs, and wallcoverings soften the echoes in a room. Trees, traffic, and fountains set the tone of a city. Beeps and buzzes mark our interactions with products. Whether heard with the ears or felt with the body, sound envelops us in the rich murmur of being.

It is now estimated that humans can, in theory, smell at least one trillion distinct scents, but no one has made a definitive claim regarding the number of smells an individual can differentiate. Unlike hearing and sight, whose mechanics and molecular biology have been exhaustively mapped in the course of the twentieth century, there is little agreement on how smell works.

1. Our sense of smell is beyond doubt a tool of great precision. Strange, then, that in the history of Western philosophy it should be so little discussed, and so often dismissed as subjective. Smell has been held in low esteem since the height of the Enlightenment. When Condillac, in his *Treatise on the Sensations* (1754), imagined a statue that would be granted all the capacities of thinking and feeling one by one, smell was the first capability he bestowed upon it, because he held smell to be the most primitive of senses and the one that contributes least to the mind. Condillac maintained that, should his statue smell a rose, it would not thereby gain any concept of the rose as an entity distinct from itself. When it smells a rose, it simply exists within the sensation of the scent of a rose. Smell, this position implies, teaches us nothing about the outside world, but produces pleasant or unpleasant sensations that go on to determine what we desire, rather than what we know.

1.1 This demotion of smell has continued more or less uninterrupted, as demonstrated by the manner in which Septimus Piesse attempted to defend the utility of perfumes in his 1857 book *The Art of Perfumery and Methods of Obtaining the Odors of Plants*: "Of the five senses, that of smelling is the least valued, and, as a consequence, is the least tutored; but we must not conclude from this, our own act, that it is of insignificant importance to our welfare and happiness. By neglecting to tutor the olfactory nerve, we are constantly led to breathe impure air, and thus poison the body by neglecting the warning given at the gate of the lungs. Persons who use perfumes are more sensitive to the presence of a vitiated atmosphere than those who consider the faculty of smelling as an almost useless gift."

A. Chlorine (Cl_2 at room temperature and pressure) is a pale green gas that was described by the soldiers that first encountered it in Ypres in 1915 as having a distinctive smell partway between pepper and pineapples. The characteristic acrid odor we associate with chlorinated swimming pools is not that of chlorine itself but of chloramine (NH_2Cl), the product of a reaction between chlorine and an organic molecule. When a pool smells intensely of chloramine, it's an indicator that the water is dirty, not clean, and the persistent smell that we carry for hours after a swim is the smell of free chlorine molecules reacting with our hair and skin. We become conscious of chlorine, in its peculiar chlorineness, at a concentration of three parts per million. At five parts per million it produces a choking sensation. At thirty it induces coughing and vomiting. At sixty it begins to corrode the lungs.

2. Kant makes almost no reference to smell in the *Critique of Judgment* or elsewhere in his writing on aesthetics. He does, however, discuss smell at length in his *Reflexionen zur Anthropologie*. There, he makes a curious distinction between the senses by which we as rational beings come to know things, and the senses that work on a more intuitive basis. Looking at things, hearing them, and even touching them require *Wahrnehmung*, or perception. But smelling things, like eating them, involves a sort of carnal knowledge, *Einnehmung*, or ingestion. By smelling things, we absorb them directly into our bodies, and consequently they provide what Kant otherwise attributes only to God: unmediated knowledge of the thing in itself. To prevent this from becoming a crisis for his epistemology, Kant argues that experiences of smell or taste are things that we are interested in, personally, and compromised by in both senses of the word. This prevents us from the sort of disinterested contemplation that aesthetic experience requires. Kant's dogmatic exclusion of taste and smell from the aesthetic has been either reproduced without question or thrown out of court (see Frank Sibley's essay "Tastes, Smells, and Aesthetics"), but no one seems to have considered that maybe he was half-right. Smell is deeply connected with the unconscious, divorced from representation, and consequently in some respects more primal than the other senses. It indicates a royal road to our animal and emotional being, offering a way of thinking, or at least of drawing conclusions, that is not conceptual but intuitive.

2.1 Smells have two qualities that make them ill-suited to the Enlightenment project of establishing a firm foundation for our knowledge of the world. First, they do not persist. Most smells are fleeting — the smell of violets (methyl ionone) is famous among perfumers for persisting for only about half the duration of an inhalation before it becomes imperceptible. Other scents are more persistent, but even the most penetrating perfume becomes undetectable to the wearer after a short period of time.

2.2 Second, as Kant writes in *Reflexionen zur Anthropologie*, "all the senses have their own descriptive vocabularies, e.g. for sight, there is red, green, and yellow, and for taste there is sweet and sour, etc. But the sense of smell can have no descriptive vocabulary of its own. Rather, we borrow our adjectives from the other senses, so that it smells sour, or has a smell like roses or cloves or musk. They are all, however, terms drawn from other senses. Consequently, we cannot describe our sense of smell" (our translation).

2.2.1 Kant's observation does not seem to be a limitation of his Baltic Sea dialect. There are also no words in the English language that are exclusively devoted to describing a smell. All the other senses have a specific vocabulary that is part of everyday speech and in no way technical (*bright, loud, hard, soft, smooth, bitter*, etc). Smell proceeds entirely via euphemism. Typical words for describing citrus scents include fruity, refreshing, sweet, sharp. "Fruity" is derived from a noun. "Refreshing" is stolen from an affect. "Sweet" belongs to taste. "Sharp" to touch. The word citrus, in toto, is useless for anyone who has not smelt citrus already, and none of the descriptive words belong to the sense of smell except in a metaphoricalsense.

B. A curious piece of trivia claims that all medical anesthetics are olfactants, that is, they have a peculiar and identifiable smell, even though smell is not part of their purpose. From chloroform on, synthetic molecules designed to knock you out (things you couldn't possibly have evolved to be able to experience) have distinct odors.

3. Freud said that "wishes are immortal." In this respect, smells and wishes are the same. The passage of time, which rots and corrodes the content of visual memory, has no measurable impact on the olfactory memory. On the condition that a smell is linked to an emotionally significant episode, the ability of specific smells to trigger episodic memories is immortal (the Proust Effect). Strangely, we are terrible at recalling the impression of smells — nearly as bad as we are at remembering physical pain. It's easy to recall the shape and color of a lemon, but almost impossible to conjure up its absent scent.

3.1 Speaking of Proust. Those oft-cited madeleines that are supposed to have triggered the reminiscences of *À la recherche du temps perdu* are traditionally flavored with almonds. Almonds have a sweet, penetrating, enduring odor that makes them particularly well suited to forming memories around. It is this quality that makes almonds such a common feature in recipes associated with annual rituals such as Christmas. It is questionable whether Proust would have been able to fill as many pages if his memory had been triggered by a highly anosmic scent, such as violet.

C. Is the sense of smell really subjective? Zookeepers have long noted that the smell of tiger urine resembles fragrant basmati rice. It was only in the course of the 1980s that Indian biologists realized that the same molecule is active in both — 2 acetyl-1-pyrroline. Furthermore, it's been noted that we can detect certain pyrazines, such as 2-isobutyl-3-methoxypyrazine — which is found in peas and paprika — at a concentration of 1 part in 500,000 million, that is, virtually molecule by molecule.

4. The olfactory bulb in humans is relatively small compared to that in, say, a white-eared opossum, a West European hedgehog, a polar bear, or a domestic dog, especially when taken in proportion to the size of the brain. But the number of human genes that encode scent turns out to be unexpectedly large. According to Linda B. Buck and Richard Axel's research, about one thousand genes code for proteins that are expressed only in the olfactory epithelium. This means that roughly 3 percent of the human genome is devoted to the olfactory system. That's an enormous share.

4.1 The olfactory bulb feeds directly into the limbic system, the seat of both long-term memory and the emotions. The results of smelling are processed here, and loaded with associations, before they even reach the upper cortex, where language is composed. This is unlike the sense of sight, in which knowing and naming are intimately interconnected activities. In a peculiar way, smelling short-circuits conscious thoughts. It bonds to memory and emotion before it subjects itself to concepts, and emerges as already a part of the bodily unconscious.

4.2 Although there has been substantial research on the olfactory bulb, olfaction is dwarfed by the other senses in the amount of research committed to it, and ignored in undergraduate studies (a 2008 textbook on cognitive neuroscience offers a chapter on sight, another on touch, but exactly two sentences on smell). This might have something to do with the following: no one agrees on how smell works. Although the problems posed by hearing and sight on the cellular level were to a large degree cracked by the 1950s and 1960s, there is still no consensus on how a molecule of olfactant entering the nose brings a single neuron to fire.

4.3 In 1996, Luca Turin — a research biologist and well-known perfume reviewer—resurrected an exotic theory of the sense of smell that had first been mooted and dismissed in the 1950s. It suggests that the smell of a compound is not dependent on the shape of the molecule (although this is the standard hypothesis, as “lock and key” ligand-binding is the mechanism by which most chemical signaling within the brain takes place, as well as the way in which the immune system functions). Rather, Turin solves the combinatorial problem of smell by arguing that embedded in the cell membrane is a kind of electron-tunneling spectrograph, and so the smell of a molecule is dependent upon its chief vibrational resonance.

D. The port wine magnolia has small purple and white inflorescences that smell distinctly like nail polish remover (acetone) and wine jujubes. The scent is strong, sweet, and slightly nauseating. Other magnolias smell like citrus. Not exactly like citrus, but somewhat like - citrus. Is acetone a pollutant that is actually found in cheap port wine?

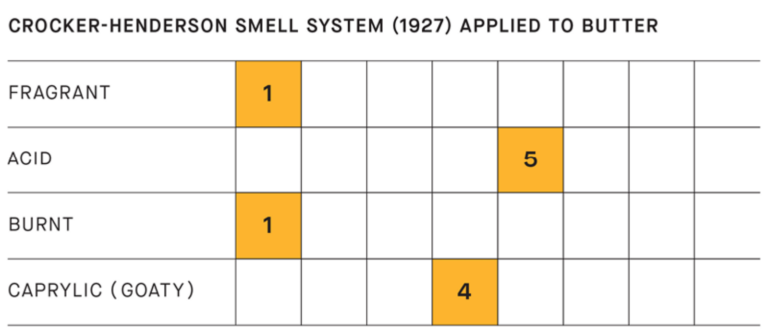
5. The relationship between smell, long-term memory, and emotion is not a trivial one, and it’s not meaningless to say that they’re all one thing. Everyone knows that smell evokes strong memories, but the relationship works both ways. The olfactory bulb is the only part of the brain that continues to grow throughout our lives, and constantly generates new neurons (Buck and Axel won a Nobel prize for figuring this out). The ability to recognize common smells is now used as a diagnostic tool in identifying neuro-degenerative diseases. People with memory loss — Alzheimer’s patients — have massively reduced sensitivity to smell.

E. Real musk is obtained from the dried gland of a wild male deer, and fresh from the wild it has a repulsive smell. Harvesting musk involves hanging out in forests during mating season with a high-powered rifle, shooting a medium-large mammal, cutting out a small gland, and then taking and preparing that gland for a luxury product. Hunters can't tell whether the deer in their sights is a buck or a doe, and consequently half of the animals they shoot are the wrong sex. That's one reason for synthetic musks. Another is that real musk is a mélange of chemicals that will cause some wearers to break out in hives. The first synthetic variant — Musk Xylol — was produced in 1888, and as the industry bible by Steffen Arctander notes, it is a close relative of trinitrotoluene, or TNT. Attempts to synthesize Musk Xylol in commercial quantities have been responsible for serious explosions in fragrance laboratories, and the death of more than a few fragrancers.

6. It is as if, when chemistry evolved out of alchemy to become an Enlightenment science, smell was left behind. Appropriately, the perfumer behaves more as a member of a medieval guild than as part of a contemporary scientific discipline. Alchemists guarded their mysteries, whereas chemistry is based on peer review and the broadest possible dissemination of results. Perfumers are likewise notoriously secretive about their ingredients, even though the field involves the mass production of tons of refined chemical products. They are even loath to talk about how they arrange their fragrance libraries (this seemingly innocent question was in fact the impetus for this text). There is a legal reason for this: it's not possible to patent a scent. You can patent the individual synthetic molecules that might be used in a scent, but you can't patent what something smells like in the same way that you can patent the way in which a product looks and feels. Knockoff perfumes are prosecuted for copying the packaging of the original, not for smelling identical. As a result, perfumers are particularly clandestine about what's in their bottles. The other reason for their secretiveness is that, even if they want to talk about what they are doing, they seem to find it pretty difficult.

6.1 Systems of smell resemble medieval bestiaries that have swollen in population without gaining in order. Aristotle classified smells into five categories. Carl Linnaeus's system contained seven categories, but by the early twentieth century Hendrik Zwaardemaker's had risen to nine. René Gerbelaud's system from the 1950s encompassed forty-five categories, and a decade later Steffen Arctander's included eighty-eight separate groups. Even more striking than the increasing complexity of the proposed systems is the parallel proliferation in the taxonomies themselves. A comprehensive taxonomy of taxonomies is hardly possible, but we can enumerate a few.

6.2 Ernst Crocker and Lloyd Henderson's 1927 model derives many of its terms from Zwaardemaker's model of 1895, which itself draws from Carl Linnaeus's original taxonomy of 1756. According to Crocker and Henderson's ingenious scheme, each odor can be considered in terms of the extent to which it is fragrant, acid, burnt, or caprylic (goaty), each on a scale of 1 to 8. Thus, vanillin has an odor of 7122. Unfortunately, there is often disagreement as to the precise score to give a scent on each of its characteristics, although Crocker and Henderson do try to provide a structured language for comparing scents.



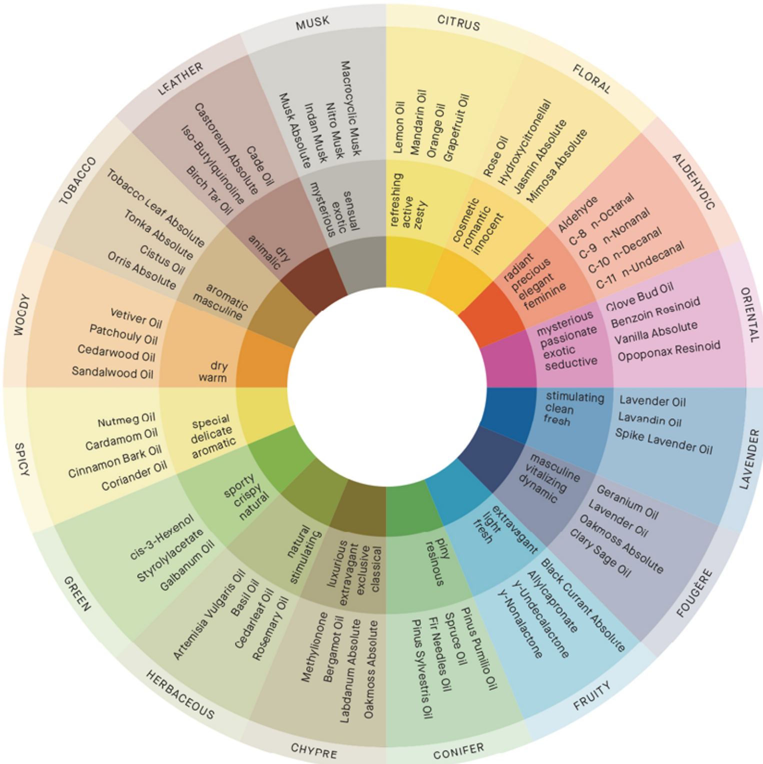
A chart has eight columns and four rows. The rows identify four aspects of smell: fragrant, acid, burnt, and caprylic (goaty). In each row, one column has been highlighted, indicating the intensity of the smell on a scale from one to eight.

THE CROCKER-HENDERSON SYSTEM. The smell of butter is ranked from 1 to 8 in four dimensions. Butter is somewhat acidic and goaty, but neither burnt nor fragrant, so its number is 1514. See Stephen W. D. Dowthwaite, "Odor Classification," perfumersworld.com/article/odor-classification

6.3 Some industrial scent manufacturers arrange smells into a sort of "color wheel" in order to describe them. But this is a weak analogy, as smells, unlike colors, do not naturally form a continuous spectrum. The Drom spectral wheel, for instance, implausibly places citrus directly next to musk, but spatially opposite "fruity" scents. Different wheels have been proposed, but their insufficiency is highlighted by their proliferation.

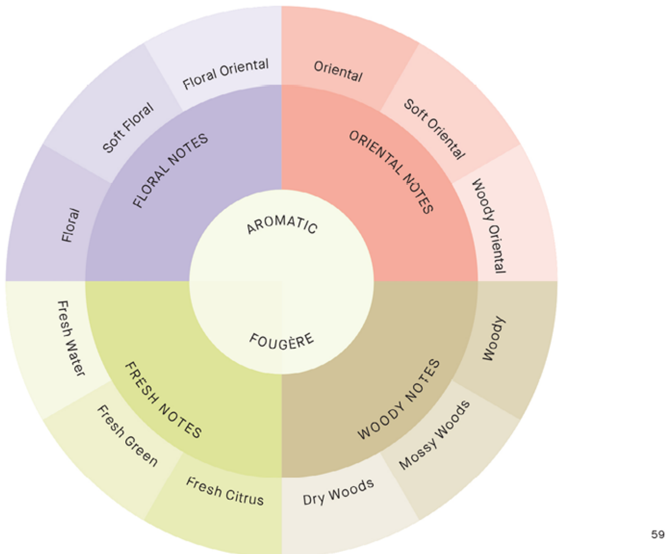
F. Ambergris is another highly valued ingredient in perfumes. It is made of a sort of fatty hairball, coughed up by a sperm whale, that then floats upon the surface of the ocean. Over time it darkens to black, and its scent mellows until it becomes what is described as a "soft, suave, dry-mossy, musty, and seaweed-like fragrance that is extremely difficult to duplicate with complete fidelity." The trade in ambergris is now banned, and a wholly synthetic version of the scent, Ambroxan, is sold in its place.

6.4 Even fragrance wheels specific to the perfume industry (such as Michael Edwards's 1983 version) are not designed as an objective tool for the fragrancers, but as a marketing guide for clients. To make matters worse, it seems that we are particularly susceptible to being suckered when we are told what we "ought" to be smelling. As Trygg Engen notes: "The associative strength of an odor-name pair is weak and asymmetric and is easily influenced by the verbal factor" (p. 502). In other words, if someone offers you a bad synthetic frambinone and tells you it's strawberry, you'll believe them, and if they ask you to sniff onion and tell you it's garlic, you'll notice nothing amiss.



A wheel is divided into wedges, like a pie. The colors of the wedges are more intense at the center. Labels describe categories such as floral, citrus, musk, and leather.

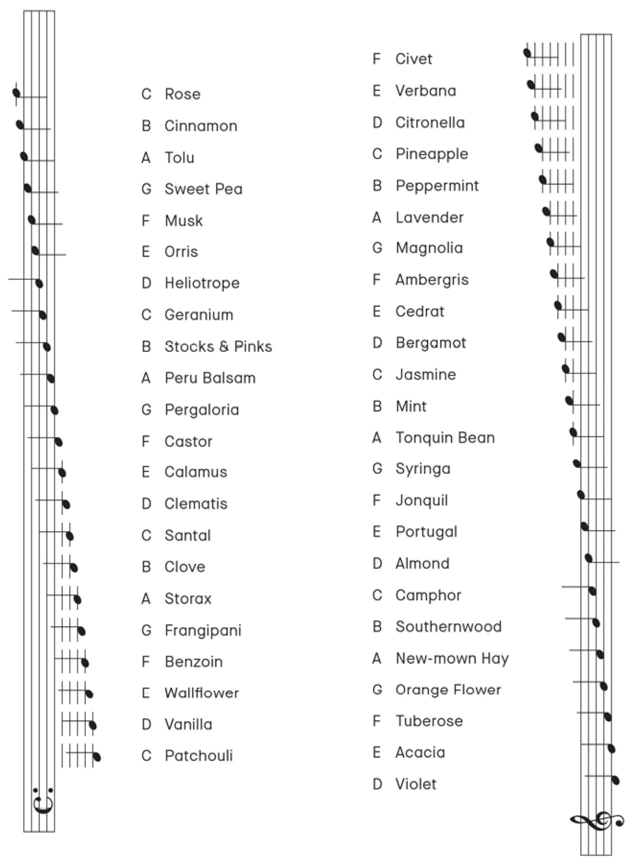
DROM FRAGRANCE WHEEL; Developed by Drom, a global scent company founded in Germany in 1911



The circle is divided into wedges and rings of color, labeled with names for different smells. This diagram was created by a perfumer to describe the sensory components of a fragrance. At the center, a small white circle is labeled "aromatic" and "fougère" (fern), establishing two broad categories. The next ring has four wedges: floral notes, oriental notes, woody notes, and fresh notes. The outer ring contains another level of detail.

FRAGRANCE WHEEL, 1983; MICHAEL EDWARDS

6.5 There have been more inventive attempts to taxonomize odor. In the nineteenth century, Septimus Piesse arranged smell on a musical scale to show how harmonious perfumes could be composed, a better (more multidimensional) approach than a linear spectrum. He was the first to apply the term "note" to a distinctive odor, as well as introducing the terms "chord," "harmony," and "progression," all metaphors that are still current in the perfume industry. Piesse proposed that "sounds appear to influence the olfactory nerves in certain definite degrees," and that "there are octaves in odors like octaves in music." Piesse took his model quite literally. According to his theory, a harmonious fragrance can be composed by bringing together those odor notes that correspond to harmonious musical chords. Conversely, discord, a cacophony of smells, is the result of combining olfactory notes that would produce discordant sounds if played musically together. In his invention, Piesse resembles Des Esseintes in Joris-Karl Huysmans's *Against Nature*, the great novel of dandyism, who composes for himself a "taste symphony" by assigning a different note to each liqueur. Via this artifice, Huysmans's character could play himself his favorite refrains from classical music by sequentially tasting various spirits.

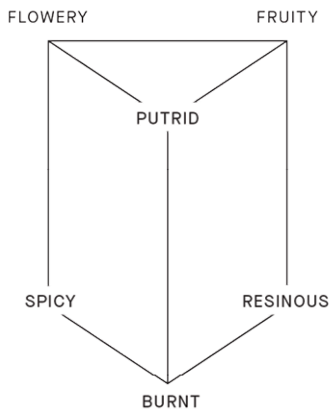


Musical staffs run vertically. Alongside them are names of different smells.

A MUSIC-INSPIRED TAXONOMY OF SCENT; created by English chemist and perfumer George William Septimus Piesse in his seminal book *The Art of Perfumery* (1857)

6.6 Perhaps one of the most interesting models is the Henning Odor Prism, or Henning Olfactory Prism (1915–1916). The prism has six apexes and five faces, and allows for any smell to be described in terms of the six categories: flowery / fruity / putrid / spicy / burnt / resinous. This would not be a substantial addition to extant theories, except that Hans Henning goes on to argue that all smells can be described as being on the surface of the prism, but not within it. Therefore, a smell cannot be spicy, burnt, and resinous as well as being putrid, and likewise, a fruity, flowery, putrid, and spicy odor cannot exist. In making assertions of this kind, the Henning Prism is at least putatively falsifiable, unlike most other smell models. This is no small virtue.

6.6.1 The Henning Prism becomes more interesting when one notes the subgroupings that the on-the-surface rule implies. Cover two of the terms at a time, and look again at the set of characteristics flowery / putrid / spicy / burnt versus the set fruity / putrid / burnt / resinous. It could be argued that both groups have enough terms to adequately describe any smell, and there is a risk of that, but that isn't what Henning intended. What is it about these two groups that make them mutually exclusive? Certainly the flowery / fruity / spicy / resinous — the general realm of attractive smells — can coexist, but not together with the putrid and burnt. The putrid and the burnt both mark out forms of decomposition. The putrid indicates metabolic decay carried out by simple life forms, whereas the burnt is the rather more chaotic decay caused by heat (both processes are marked by increasing variety but reducing complexity in the organic molecules present). Whereas flowery and fruity scents may, in their freshness, have much in common, according to the Henning Prism they differentiate themselves from each other in their odor profile during decomposition. Also, it is noteworthy that the flowery / fruity / putrid (less stable) and the spicy / burnt / resinous (less volatile) take opposite ends of the Henning Prism.



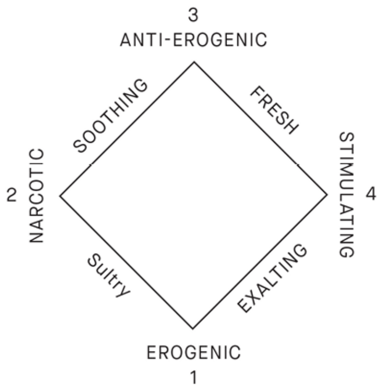
This triangular prism resolves the problem of how to visually depict the complex variability of smells by presenting them as points on the surface of a three-dimensional model.

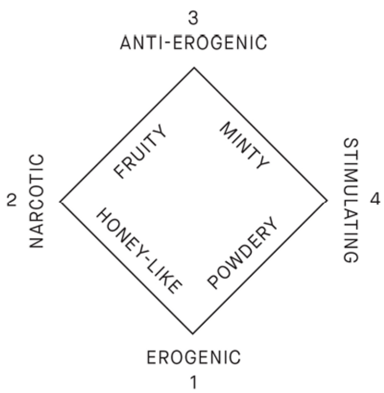
ODOR PRISM, 1915–16, Hans Henning.

6.6.2 Intriguingly, the Henning Prism also suggests the possibility of charting “smell trajectories,” that is, the characteristic changes in smell as a perfume’s volatile top note lifts to reveal its middle and base notes, as when a fruit ripens or when an organic product undergoes metabolic decomposition. By what habitual route does an unripe peach slowly lose its spicy, flowery characteristics to sweeten into an odor more fruity and perhaps more resinous? And via what path does this scent become putrid as the peach begins to rot? Is it curved, or straight?

6.6.3 Henning attempted to relate different chemical groups to the various sections of his prism, noting, for instance, that the category of the putrid is marked by volatile sulphides. Unfortunately, while some molecules might have predictable characteristics, as in a bad grammatical model, there are nearly as many exceptions to each category as well-behaved instances that fit the rules.

6.7 In 1951, Dr. Paul Jellinek proposed a new scheme for the classification of scents. Although a professional perfumer, his system (which was restated in *The Psychological Basis of Perfumery*, 4th Edition, 1997) has the virtue of attempting a degree of generality. The schema, however, is tendentious in the worst sense. As Jellinek held that the sense of smell is enthralled by sexuality, he arranges all odors on a scale based on their purported psychological effect. One axis connects the erogenic to the anti-erogenic; another axis runs from the narcotic to the stimulating. Following Jellinek, cheesy smells are both highly erogenic and slightly stimulating, whereas fruity smells are anti-erogenic and somewhat narcotic. The problem, of course, is that as soon as one questions the psychological model behind the classification, the schema collapses. And in spite of all the enthusiasm about pheromones, they remain more or less mysterious. It's also not advisable to buy synthetic pheromones from dispensing machines in toilets, as androstenones, the closest pheromones to humans that have been extensively synthesized, are from the porcine family (*Suidae*). The only mammals that you are likely to arouse irresistibly are pigs.





DR. PAUL JELLINEK'S CLASSIFICATORY SYSTEM, 1951

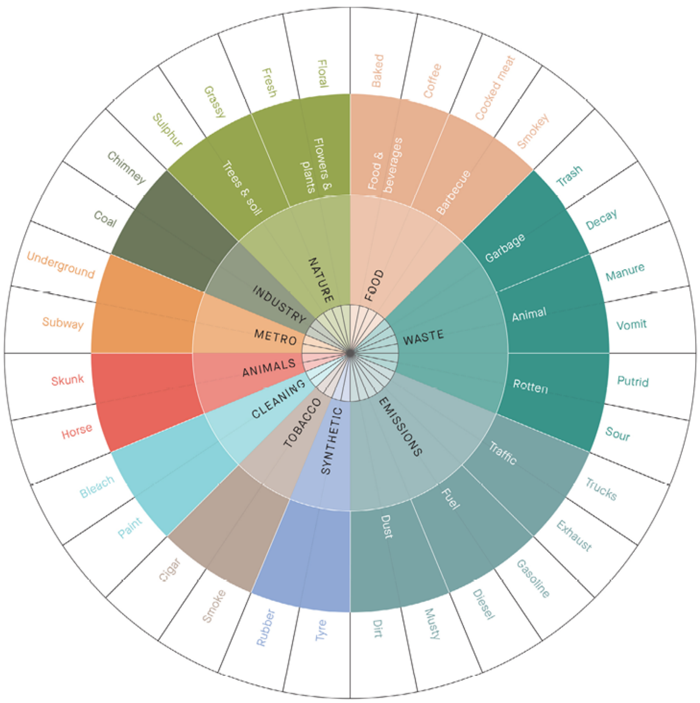
7. Luca Turin's thesis of the vibrational basis of smell has come up against entrenched opposition from the scientific establishment. Perhaps, here again, it is the enchantment of the diagram that is responsible, for should his argument prove to be correct, the wire-frame and space-filling molecular models that mesmerize fragrance designers worldwide would have precious little relevance in predicting how a chemical will actually smell. The thousands of line drawings of organic molecules that fill fragrance textbooks will turn out to be as much a fetish as Piesse's musical scale, because we have been studying the wrong characteristics.

7.1 In the 1980s, the chemist Roman Kaiser developed a procedure based around gas chromatography and mass spectrometry that promised the possibility of objectively capturing and recording the olfactory molecules in a sample of air. Artists and experimenters have seen in the invention the possibility of a new media format, something akin to a photography of smell. But according to Professor Kaiser, the enthusiasm is misplaced. Because the sense of smell is nonlinear in its sensitivity, a powerful scent at an undetectably low concentration — such as a pyrazine — can have a stronger impact on the senses than a pervasive gas. As a result, no currently imaginable technology can offer a reliable means to capture, store, and reproduce the scent of a place.

G. Oak moss has a particularly wonderful smell — neither vegetable nor animal, but richly aromatic. The moss grows only on oak trees, and only in the most established and ancient woods. For a very long time, the majority of it was harvested in Yugoslavia. However, it soaks up radioactive waste more effectively than just about any other life form, and ever since the Chernobyl disaster in the Ukraine, it has been exceedingly rare and expensive, because so much of it is too contaminated to use.

Wedges of color radiate from the center of the circle, labeled with categories such as food, waste, emissions, and animals.

URBAN SMELLSCAPE AROMA WHEEL, REVISED 2017; Kate McLean (British, b. 1965), Daniele Guercia, Rossano Schifanella, Luca Maria Aiello; Courtesy of Kate McLean. To arrive at this taxonomy of urban smells, Kate McLean led walks through Amsterdam with local residents, who identified 650 smell impressions.



8. In conclusion, smell is not subjective; rather, it is simply very hard to communicate objectively, that is, to talk about and achieve any sort of consensus. One possibility would be to unwind the “color wheel” model, and ask how many dimensions it would have to incorporate in order that all its observable contradictions disappear. Much like experimental versions of Mendeleev’s original periodic table, there are interesting possibilities for new spatial models for representing scents. Perhaps future models of smell will have to address similar orders of complexity, and the solution just hasn’t been drawn up yet. Alternatively, there may simply be no way to represent

visually the variability presented by scents.

9. In *Civilization and Its Discontents*, Freud tells an originary myth, in which Man goes from walking on all fours to standing erect. As he does so, the genitals are exposed, the sense of sight is privileged, and the sense of smell is denigrated. Whether or not the story refers to an actual historical event doesn't matter; Freud's pointis that somewhere in our development, we learn shame for what has become the spectacle of shit and lose the capacity to smell it with any finesse. However, there's a simpler physical explanation for why walking on two legs might lead to a demotion for the sense of smell: olfactants are heavier than air, and consequently they fall to the ground. If you want to make a map of how your room smells, you need to get down on your hands and knees.

10. And finally, how do professional perfumers arrange their smells? *Alphabetically*, of course.

Essay first published as “Notes on Smell” in *Cabinet*, Issue 32: Fire (Winter 2008/09). Reprinted herewith revisions. Figures redrawn by David Genco

FLAVOR | Ellen Lupton

Flavor engages all the senses. As you bite into a ham sandwich and feel its layers mash together inside your mouth, the tongue seems to be the master of sensation, roused by grains of mustard, plumes of salt, strands of protein, and an earthy afterglow of rye. A simple bite of sandwich mobilizes more than the tongue, however. Texture, aroma, temperature, and appearance, as well as language and memory, all contribute to the complex experience of flavor.

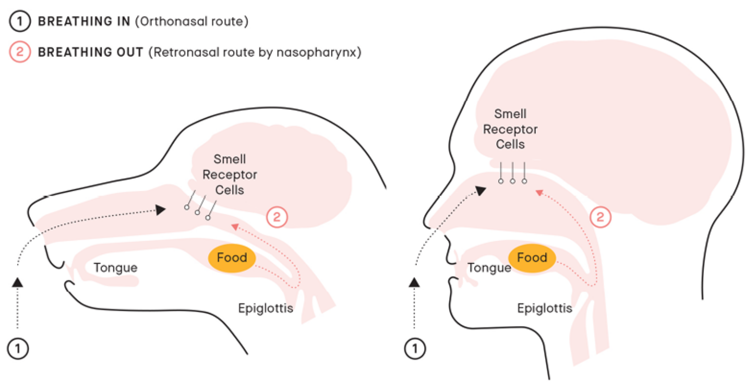
Flavor is taste

Bundles of cells called taste buds populate the folds of the tongue and the back of the mouth. Responding to chemicals in food and drink, taste buds are tuned to differentiate just five channels: sweet, salty, sour, bitter, and umami. The tongue's five unique receptors transmit their signals separately to the brain, where the "taste cortex" creates a sensory map. "The beauty about taste is that it has limited chemical space. There are only five basic qualities and each of them has an innate and very well-defined meaning and valence," says Dr. Charles Zuker, scientist at Columbia University College of Physicians & Surgeons. "So the taste system provides a powerful platform to understand how the brain functions: how complex, hardwired circuits operate, how they are modulated, and how they are used to guide actions and behaviors."[1]

Flavor is smell

The olfactory bulb is a more sophisticated instrument than the human tongue, with its sharply limited sensory range. Smell receptors help the brain detect at least one trillion different aromas. Smell is thus the most discriminating of all the human senses. The eye can differentiate several million colors, while the ear makes sense of fewer than half a million tones.[2] Gordon M. Shepard's work on "neurogastronomy" upends the myth that humans have a poor sense of smell. Dogs, of course, are legendary sniffers, capable of tracking a fox through dense undergrowth or detecting a tiny bag of heroin deep inside a cargo hold. Sniffing, however, is not where humans excel. To sniff is to breathe in, drawing air into the nose to receive smell.

The triumph of the human nose occurs not when we breathe in, however, but when we breathe out. This process is called "retronasal olfaction." (Sniffing is "orthonasal olfaction.") The process of chewing food and mixing it with saliva releases volatile compounds, bathing the tongue and mouth with aromatic matter. Air passing out of the body carries smell molecules to receptors located at the top of the nasal cavity, and it is here where some of our most powerful messages about food are born.[3]



A diagram cuts through the head of a dog and a human, showing the shape and location of their nasal cavities and cell receptors. Arrows show the passage of smells into the mouth and nose while breathing out (orthonasal route) and the passage of smells leaving the body (retronasal route).

DOGS ARE TALENTED SNIFFERS. They distinguish odors with astonishing precision while inhaling air through their noses. Their long snouts enhance their sniffing skills. Humans outperform dogs when it comes to experiencing smells while breathing out. Humans can sense a vast number of different flavors, a process that relies on the retronasal route (air passing out, not in). Odor compounds travel on a direct route from the back of the mouth to the nasal cavity. Diagrams by David Genco, redrawn from Gordon M. Shepard, *Neurogastronomy: How the Brain Creates Flavor and Why It Matters* (2012). Used with permission © 2012 Columbia University Press.

Flavor is primal

The taste buds that pepper the tongue and mouth transmit data to the brain stem, a primitive area in charge of involuntary actions such as breathing and digestion. In the brain stem, taste triggers preconscious responses such as attraction or revulsion. The brain stem sends along taste signals to higher-level areas of the brain, where they merge with aroma and other sensations to build a full perception of flavor.

Flavor is emotional

In contrast to the simple tongue, the madly sophisticated nose communicates with the olfactory cortex in the brain's limbic system. This higher-level brain structure is dedicated to memory and emotion. The olfactory cortex also connects to part of the brain controlling judgment and planning. Our ability to differentiate an enormous range of flavors reflects the highest human faculties of thought and consciousness — faculties that rely on our extraordinary sense of smell.

Flavor is tactile

The sensation of eating doesn't stop with taste and smell. Touch receptors embedded in the skin of the mouth and tongue react to food's unique physical qualities. The movements of the tongue and jaw further shape our perception, as we experience the relative hardness, resistance, or granularity of the food we eat. Food can be smooth, slippery, gooey, gluey, glossy, stretchy, creamy, or fluffy. A slice of apple or a wedge of cheese changes as we chew, crush, swish, and swallow it. A spoonful of pudding slides down the throat, while a hunk of sirloin gives up a mighty fight. We also react to food's physical temperature and to the perceived heat of pepper or the coolness of mint. This diverse group of responses constitutes the mouthfeel or mouth-sense of food. Mouthfeel is a somatosensory phenomenon: *soma* (body) plus sensory. These embodied responses loom large in our perception of food and drink. Texture and temperature contribute to our instinctual belief that flavor resides in the mouth rather than the nose.

The handle of the dessert spoon is lacquered in deep red, its head lacquered in cherry red. Small bumps are studded along the rear side of the spoon. One small bump appears on the handle tip.

AEIOU VI REAR BUMP SERIES, from the Sensory Dessert Spoon collection, 2016; Jinhyun Jeon (South Korean, b. 1981), Studio Jinhyun Jeon (Eindhoven, Netherlands, founded 2012); Ottchil-lacquered plastic; 2.8 × 2.2 x 13.3 cm (1 1/8 × 7/8 × 5 1/4 in.); Courtesy of Jinhyun Jeon

Flavor is visual

Visual cues — especially color — influence our perception of flavor. Color perception may have helped early humans know when fruit was ripe on the tree and find the yellow bananas in a sea of green. A human's ability to see color thus conferred an evolutionary advantage.[4] Vegetables pulped into a gray mass repel the appetite. Such mush suggests rot and decay — as compared to a fresh, bright salad. Designers use color to influence flavor experiences when they create packages, patterns, and surfaces that evoke or amplify sensations of taste and smell. A deep, warm brown evokes the buttery bitterness of chocolate. A greenish hue of yellow evokes the woodsy balm of citrus. A purple jellybean tastes something like a grape.

Flavor is aural

People munching popcorn in a movie theater hear it from inside their own heads. They can also hear the munching sounds of moviegoers in surrounding seats, as well as the clatter of ice cubes and the crinkle of candy wrappers. Eating makes noise. In Japan, slurping soup is an acceptable sign of gustatory pleasure; not so at a traditional Western dinner table. Sound and texture merge in words like "crispy," "crunchy," "crackly," and "fizzy." The English word "snack" sounds as crisp as a bag of pretzels or chips.

Experimental psychologist Charles Spence studies the effects of sound on flavor. In a 2004 experiment, participants were asked to eat and evaluate Pringles potato chips. A Pringle is produced from a smooth potato slurry, yielding a perfectly blond, uniform wafer. As the subjects ate these identical salted snacks, Spence's team piped crunching sounds into headphones worn by each subject. Unbeknownst to the subjects, Spence's team was altering the loudness and frequency of the sounds. Participants tended to believe that the chips consumed with a louder, higher-frequency sound track were fresher than those with a quieter, lower sound.[5]

Flavor is contextual

Environmental factors change our flavor experiences as well. Designs for menus or packages prime our judgment of an item's freshness, cost, nutrition, and flavor. According to Brian Wansink, who has devoted his career to improving public health with behavioral psychology, "Most of us don't overeat because we are hungry. We overeat because of family and friends, packages and plates, names and numbers, labels and lights, colors and candles, shapes and smells, distractions and distances, cupboards and containers."[6] Wansink encouraged the US food industry to introduce 100-calorie snack packs, an antidote to king-size portions

Flavor is a Gestalt

The brain fuses together scent, taste, texture, and other qualities. Flavor is a unified sensory object — a Gestalt — that unfurls in time and space. The flavor of strawberries is not merely sweet and tart; it derives its flowery, fruity aroma from a cocktail of chemicals, including acids combined with alcohol (called ethel esters) and furaneol, a chemical also found in pineapple, which has a nutty, caramel aroma.[7] The juicy meat of a strawberry is not the fruit itself, but is in fact auxiliary tissue beaded with hundreds of achenes, each one a tiny fruit enclosing a tiny seed. Those seeds give the strawberry its pocked and pebbly skin. A strawberry is a complex organism with a layered anatomy. Strawberry is also a myth, a cultural idea. It is the pink stripe that follows chocolate and vanilla. It is a symbol of sensory delight, a crucial node in a dictionary of iconic flavors.

Sensory Materials

Ellen Lupton & Andrea Lipps

Paper or plastic, silk or wool, rubber or resin? Materials define the character of places and things. A surface could be hot or cold, hairy or slick. It could absorb waves of light or sound, or bounce echoes around a room. The tangible qualities of things include shape, smell, texture, rigidity, buoyancy, and weight. A humid day weighs us down with wetness and warmth. Fluorescent lights make a super-chilled supermarket feel even colder. Sensory design considers the many ways that materials impress the human mind and body.

In 1930, a young critic and historian of design named Beatrice Warde compared good typography to a crystal goblet. A properly designed page of text, she said, is a transparent vessel for content. Likewise, a glass of fine wine is best served in a clear glass vessel—not in a chalice crusted with gems. Among graphic designers, Warde's metaphor of the crystal goblet triggered decades of debate about form and content. She loved glass because it disappears. She exhorted designers to stay in the background, letting content take center stage.

Consider for a moment the materiality of glass. What do you see, touch, and hear? Not quite invisible, a glass of water shows itself in gleams of light. Glass pings to life as it jostles with the stuff around it. Shimmering with potential menace, glass speaks when a rock sails through a picture window or when cubes of ice drown their sorrows in a tumbler of scotch. Glass finds danger in its own fragility.

Artists Lili Maya and James Rouvelle play with the sonic qualities of glass in Pulse, Drift, Ping, Echo, assembled for Cooper Hewitt's exhibition *The Senses*. Scattered across a tabletop are a dozen or so overturned cones, domes, and droopy tubes of glass. Tiny spheres of metal roll around unbidden inside each upturned vessel. The spheres tap against the glass, making a gentle, irregular pattern of sound.

This piece is the latest in a series of installations begun by Maya + Rouvelle in 2014. Earlier pieces in the series include Tympanum Temperament, shown here. The glass artifacts were handmade by glassblowers during artist residencies at the Tacoma Museum of Glass and Pilchuk Glass School. Maya told us, "The glass pieces stem from goblets and vessels, while playfully hinting at shapes derived from the inner workings of the ear and from engine parts and plumbing fixtures." Maya and Rouvelle designed the pieces to ring and resonate, not to hold water. A glass element resembling a melting champagne flute is a delicate horn designed to conduct sound.

The little spheres rolling around inside the vessels are neodymium magnets. These powerful, rare-earth magnets appear in many commercial products, including cordless power tools and computer hard drives. Electromagnets installed beneath the tabletop produce magnetic fields. Sensors detecting changes in the electromagnetic field surrounding the piece instruct the electromagnets to switch their polarity from north / south to south / north. This causes the tiny spheres to change direction. The spheres assert their own dynamics as well, influencing one another and the larger magnetic field, in turn affecting the sensor that controls the electromagnets. Rouvelle explains, “What you see and hear on this tabletop is an example of chaos: a system of dynamic, individual elements influencing each other through complex feedback loops.” Intricate relationships yield a rhythm that is random yet textured, like the sound of falling rain.

A table top is covered with glass volumes in the shape of cones, domes, and droopy tubes. Tiny spherical magnets roll around inside..

PULSE, DRIFT, PING, ECHO, 2018; Lili Maya (American, b. 1965) and James Rouvelle (American, b. 1967), Maya + Rouvelle(New York, New York, USA, founded 2009); Glass, magnets, electronics; Sizes vary; Courtesy of Maya + Rouvelle

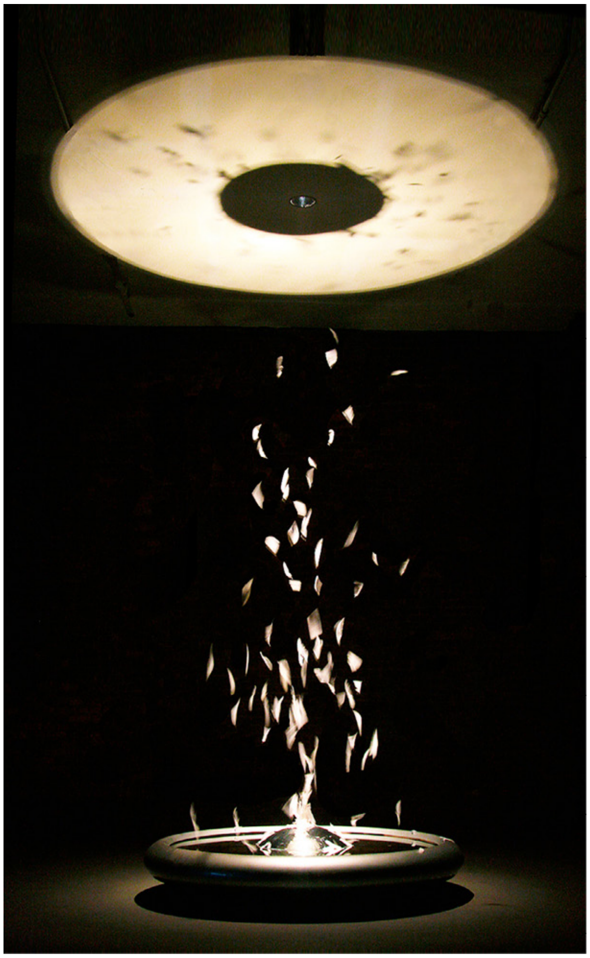
Cooper Hewitt asked Maya + Rouvelle to add a new sensory dimension to their piece: touch. Typically, the duo’s glass installations are too dangerous for direct interaction. If a visitor were wearing a metal ring, one of the tiny super magnets could leap against the surface of the glass and shatter it to bits. To create a tactile experience, Maya + Rouvelle assembled a landscape of low, reclining sculptural objects tethered to the table. Inside are mechanisms that tap against the glass or gently vibrate in response to visitors. The pulsations vary in response to the same sensors that control the electromagnets, producing a tactile variant of this series of fascinating works.

A wineglass feels smooth to the touch. It seems to have its own temperature as well. A glass vessel feels warmer in our hands than a metal fork or a chunk of marble. A tin cup filled with hot coffee will burn your hands faster than a cup made of Styrofoam. Corian countertops feel warmer than granite or stainless steel. (Each surface also absorbs sound differently.)

Why do materials have different perceived temperatures? Glass, oak, and velvet are poor conductors of heat. When you walk across a concrete floor in bare feet, heat quickly flows into the slab from your body. A wool carpet will have the opposite effect; energy stays with you longer, because wool is a weak heat conductor. The pockets of air in the carpet heighten the impression of warmth. The piled surface prevents air from flowing across it and carrying away heat, and air itself is a poor conductor. Likewise, smooth bedsheets feel cool against your body because air flows freely against their surface, while fuzzy flannel sheets trap air and feel cozy. Fiberglass (made from tiny filaments of glass) is a great insulator because glass doesn't conduct heat well, and the space between the filaments slows down the flow of air and the transfer of heat.[1]

Air is thus a crucial component of materials. It hides among the fibers of a felt curtain, and it fills the cells of a foam-rubber mat. Air is also an active, dynamic medium unto itself. Daniel Wurtzel is a sculptor who works with air. He creates clouds of fabric, glitter, or mist that rise and fall, ripple and swirl, driven by currents of air. For a production of Shakespeare's *Tempest*, he sent panels of silk soaring out into the audience to conjure a ravenous storm. For the Winter Olympics in Sochi, 2014, he made sheets of paper rise out of giant books to form a turning, twirling, diaphanous tower—a metaphor for snow and for the tradition of

Russian literature. Wurtzel's Feather Fountain brings viewers closer. Vents circling the round base shoot streams of air inward across the fountain floor. The air currents meet in the center, making hundreds of feathers levitate toward the ceiling. At a certain height, gravity takes over and the feathers float back down, only to be picked up again by the ceaseless draft. The feathers plink like raindrops when they make landfall. Each feather is itself a brilliant piece of aerodynamic design. A curious thing happens when a wayward feather drifts outside the bowl of the fountain, says Wurtzel: "People tend to pick up the lost feathers and put them back into the air column. Visitors are naturally curious to see what happens."



Hundreds of feathers rise and fall from a low, bowl-shaped base, seven feet in diameter. Light reflects up at the ceiling from a mirror in the center of the base.

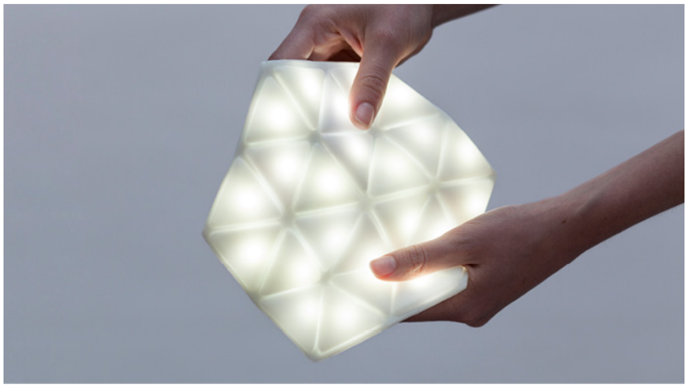
FEATHER FOUNTAIN, 2008; Daniel Wurtzel (American, b. 1962); Feathers, mirrors, fiberglass ring; 35.6 × 236.2 cm diam. (14 in. × 7 ft. 9 in.); Courtesy of Daniel Wurtzel

Light is a material, too. Light models form with shadow and contrast, and it confuses the eye with reflections and glare. Light is a symbol of truth, but it's also a trickster. Changing with time, it makes everything it touches change, too. It strikes us as warm or cool, hard or soft, depending on its intensity and color temperature. Industrial designer Theo Richardson, talking to us about how light shapes the character of a space, said, "Light surrounds us like a fragrance."[2] His company Rich Brilliant Willing (RBW) designs and manufactures light fixtures in Brooklyn, New York. From the cool white of daylight to the warm honey of a candle, light bathes people and things in a tactile glow. Richardson told us, "A room consists of layers of sensory experience—from cut glass to shaggy carpet to raw wood to the light falling from a fixture."

A round, blue, shallow lamp shade hangs from the ceiling from a swagged cord. A glass globe emits a warm glow.

LIGHTING FIXTURE, MEYER DAVIS HOIST PENDANT; Rich Brilliant Willing (New York, New York, USA, founded 2009); Cast glass diffuser, steel shade, aluminum module; 36 x 18 cm diam. (14 x 7 in.); Courtesy of Rich Brilliant Willing

Studio Banana, a multidisciplinary design studio with outposts in Spain, Switzerland, and the UK, generates playful objects with lifelike personalities. Their Kangaroo light is a sheet of quilted silicone with twenty-four LEDs hiding inside. Different settings allow the bendable, portable Kangaroo to blink, pulse, or emit a steady glow.



A soft, bendable hexagon is made of glowing, quilted silicone. It has twenty-four LEDs hidden within.

KANGAROO LIGHT, 2014; Studio Banana (Madrid, Spain; London, United Kingdom; Lausanne, Switzerland, founded 2007); Silicone, LEDs, lithium-ion battery; 19 x 19 cm (7 15/32 × 7 15/32 in.); Courtesy of Studio Banana

Sensory deprivation is another delight for Studio Banana. Their OSTRICHPILLOW is a napping tool for overworked millennials. This padded object shuts out light and sound, offering a modicum of privacy to persons compelled to sleep in public places, from office cubicles to airline seats. The masklike OSTRICH is a portable sleeping chamber—part pillow and part portable architecture. Accounting for a full upper-body experience, it includes holes for tucking the arms into a resting place beneath the head.

A padded, dome-like structure fits over the head, face, and neck. Two arm holes at the top support a user's arms when their head rests on a table.

OSTRICHPILLOW Original, 2012; Studio Banana (Madrid, Spain; London, United Kingdom; Lausanne, Switzerland, founded 2007); Viscose, elastomer, polystyrene microbeads; 45 x 28 x 15 cm (17 11/16 × 11 × 5 7/8 in.); Courtesy of Studio Banana

Materials change the sound of a room. Hard materials reflect sound, creating echoes that make a space noisy and blur the sounds of speech. Soft materials absorb sound, clarifying the sonic experience of a space. Furniture is an acoustic instrument. Wakufuru, designed by Johan Kauppi, is a family of tables and benches designed to be quiet both visually and acoustically. According to Kauppi, "Wood as a material always contributes a natural warmth to interiors. I wanted to find out if solid wood furniture could also reflect some of the sound atmosphere that is experienced in forests."[3] Produced by the Swedish company Glimakra for cafes and public places, each piece has three layers of sound-absorbing material beneath the top surface. An air gap further dampens the sound.

A blond wood bench with an upholstered seat absorbs sound.

WAKUFURU BENCH, 2017; Johan Kauppi (Swedish, b. 1975), manufactured by Glimakra of Sweden (Glimakra, Sweden, founded 1948); Wood, top in veneered MDF; Acoustic filling: formfelt, perforated board, and polyether; Sizes vary, up to 160 × 80 × 45 cm (5 ft. 3 in. × 31 1/2 in. × 17 11/16 in.); Courtesy of Johan Kauppi

Ronald Rael and Virginia San Fratello, founders of Emerging Objects and Studio Rael San Fratello, are avid explorers of the material landscape. By devising their own 3D-printing processes, they are creating forms and substances with unique structural and tactile qualities. Trained as architects, they view themselves as material scientists and cooks, "inventing recipes that would allow us to ask questions about the future of architecture through the lens of 3D printing." Objects and structures printed from salt, cement, ceramics, and plant-based plastic binders are prototypes for new sustainable construction methods that could employ materials on hand at a site. Sensuality matters, too. Exploring materials that could be eaten or consumed, they have printed vessels from coffee, tea, sugar, curry, and the skins of Chardonnay grapes.[4]

Two low, rounded cups are printed from coffee. The surface is a rich brown color with a rough texture.

COFFEE CUPS, 2015; 3D-printed coffee; Each: 7.6 x 8.9 x 5.7 cm (3 x 3 1/2 × 2 1/4 in.).

A pink candy dish has a rough, grainy surface. The dish resembles a stack of bubbles. At the top, half of one bubble serves as a lid.

COTTON CANDY DISH, 2017; 3D-printed sugar, aromatics; 30.5 × 15.2 × 15.2 cm (12 × 6 × 6 in.). Virginia San Fratello (American, b. 1971) and Ronald Rael (American, b. 1971), Studio Rael Fratello (Oakland, California, USA, founded 1995) and Emerging Objects (Oakland, California, USA, founded 2012).Courtesy of Emerging Objects.

The goblets have wide, low stems. They are a rich, deep red with a rough texture.

CHARDONNAY WINE GOBLETS, 2017; 3D-printed chardonnay skins and seeds; Each: 11.4 x 11.4 x 9.1 cm (4 1/2 × 4 1/2 × 3 19/32 in.); Courtesy of Emerging Objects

The vessel is oval in shape and has an opening on the top and a lid. There are circular handles on each side and on the top. A bumpy texture covers the vessel. The exterior is a deep, reddish brown, and the interior is orange.

FURRY CURRY, 2017; 3D-printed cement, curry; 15.2 x 15.2 x 17.8 cm (5 31/32 × 5 31/32 × 7 in.).

Textured surfaces feel warm because they slow down the flow of air. Visible textures can add warmth to any work of design—even when the texture isn't physically touched. A rough concrete wall seen from a distance or a grainy scrim applied to a digital photograph changes our mental response to what we are looking at. We touch with our eyes. The mere illusion of texture evokes past interactions with real materials. A craggy surface simulated on a screen or printed on a wallcovering stirs expectations of touch, adding depth to our encounters with flat surfaces and virtual objects.

Layers of hand-torn paper give dimension and texture to Snarkitecture's non-repeat wallpaper, Topographies. Created with Calico, the wallcovering is a two-dimensional exploration of excavation as architectural process—Snarkitecture's signature aesthetic. To create the design, founders Alex Mustonen and Daniel Arsham stacked reams of oversize cotton rag paper and tore each sheet by hand, exposing the fibers. The contours of the torn sheets resemble the curved lines used in maps to show the topography of a landscape. The texture is reproduced in such high fidelity we can imagine touching the paper's pulp and enter an otherwise unseen landscape. The paper is treated as a three-dimensional structure with interiority, revealing and concealing a process.

Two hands are tearing paper into shapes resembling the curving, concentric edges in a topographic map.

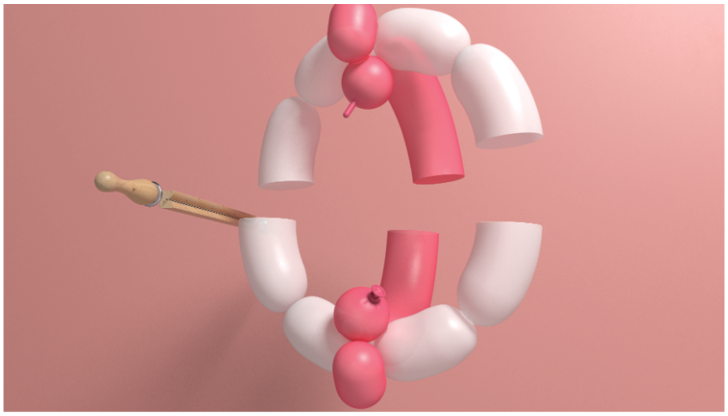
WALLCOVERING, TOPOGRAPHIES, 2017; Snarkitecture (New York, New York, USA, founded 2008), manufactured by Calico Wallpaper (Brooklyn, New York, USA, founded 2013); Vinyl; Non-repeating custom print; Photo by Lauren Coleman, Courtesy of Calico Wallpaper

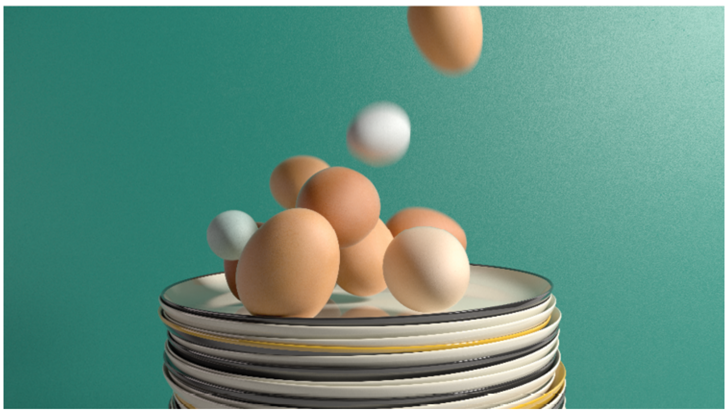
The hyperreal illustrations and animations of Wang & Söderström are populated with imaginary objects, constructed entirely with 3D software. Candy-colored objects stacked in a compact still life beg to be touched and tasted. Blobs of metallic gel shimmer in a sugary pink void. Vases manufactured from paper-thin porcelain shatter along a slow-motion path of destruction. The surfaces coating this eerie artificial world are pebbly, furry, shiny, squashy, viscous, or reflective. This work pumps up the illusory effects of today's digital rendering tools. The 3D software used by architects, product designers, and game designers is stocked with dictionaries of simulated materials. A cube or a sphere can become wood, marble, or glass with little thought about the properties of physical things. Wang & Söderström amplify the fakery of product renderings and futuristic fly-throughs to create places and things glistening with toxic allure.

A still life depicts stacks of strange objects, such as a pink, brainlike blob, metallic tear drops, cubes of composite stone, and a chunk of cobalt blue.

TREASURES 1, 2016; Anny Wang (Swedish, b. 1990) and Tim Söderström (Swedish, b. 1988), Wang & Söderström (Copenhagen, Denmark, founded 2016); 3D software: 3Ds Max, Vray, Modo; Courtesy of Wang & Söderström

Artificial objects come to life in the 3D animation *For Approval*, produced by Mainframe and directed by Chris Hardcastle. We predict how an object will behave based on sight. *For Approval* subverts those expectations. A bowling ball bounces instead of falling. A glass of milk should spill when knocked over, but this glass melts away like water, leaving behind a solid white core of milk. The texture, weight, density, and brittleness of these simulated objects can be judged and understood through visual means—and then altered for narrative effect.



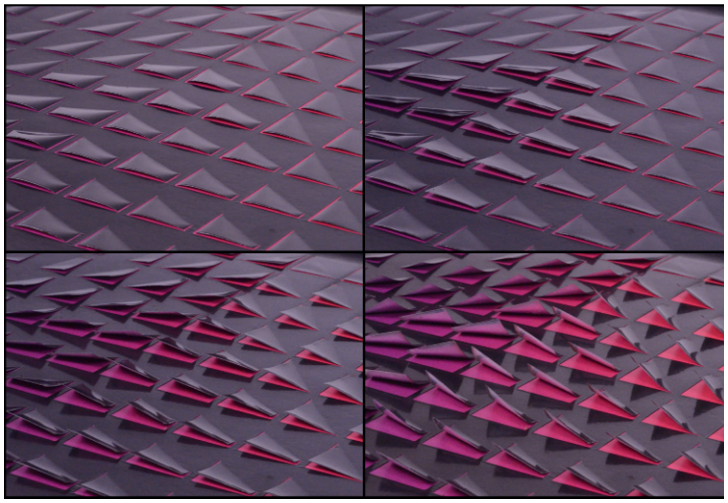


Balloons should burst when pierced with a knife, but these are as dense as sausages. Eggs dropped on a ceramic plate bounce instead of breaking, their shells deforming like soft rubber.

For Approval: Balloons (still), 2017; Chris Hardcastle (British, b. 1975), Ben Black (British, b. 1985), and Jack Brown (British, b. 1986), Mainframe (Manchester, UK, founded 2008); Autodesk Maya, V-Ray; Courtesy of Mainframe

Designers consider warmth and texture (real or illusory) when choosing materials for products or rooms. When describing a classroom filled with hard furniture and fluorescent lights as "cold," we mix and match the qualities of materials—tactile, emotional, acoustic, and kinetic. Weight and sound are important, too. How heavy is a book or a bar stool? Is a table or chair designed to be moved around or left in place? A plastic chair is easier to pick up than a metal one, and it clatters less when stacked. Is a curtain designed to drift in the breeze or cloak a room in stillness? Conservator and fashion curator Sarah Scaturro spoke to us about sound in the history of fashion. When Christian Dior launched his “New Look” in 1947, with its narrow waists and wide skirts, he was not only celebrating the end of wartime austerity but also reviving the rustle of Edwardian silk from his childhood. Beads, straw, and high-heeled shoes all make distinctive sounds. Velvet offers the opposite. Its deep pile absorbs sound as well as light.[5] Black-box theaters and hotel ballrooms are hushed by floor-to-ceiling velvet curtains.

Materials respond to their environment. Skylar Tibbits, codirector and founder of the Self-Assembly Lab at MIT’s International Design Center, conducts research into methods of “programming” synthetic or natural materials through means of self-folding, tension, or curling. All materials react to something —temperature, moisture, or friction. Laser-cut wood veneer bends, folds, and curls in on itself based on the striation of the cut. Textile structures can be designed to expand and contract in response to temperature changes. Imagine jackets, sneakers, or car seats that adapt and respond to their user’s body temperature. As Tibbits tells us, “by printing or otherwise assembling materials to optimize their response to other conditions, they can be programmed to fold, curl, and respond.”[6]



A purple surface is perforated with a pattern of slits. In four different images, the slits have peeled open in varying degrees.

ACTIVE TEXTILES, 2017–18; Self Assembly Lab, **MIT** (Cambridge, Massachusetts, USA, founded 2013); Steelcase (Grand Rapids, Michigan, USA, founded 1912); Designtex (New York, New York, USA, founded 1961); Textile combined with active polymers;

For Cooper Hewitt's *Senses* exhibition, Tibbits collaborated with Designtex and Steelcase to demonstrate how programmable materials can enter our living spaces. Perforations in a composite textile are programmed to open and close in response to light and heat. In front of a light fixture, the textile's perforations open to reveal patterned shadows cast on the wall around it. Turn the light off and the textile contracts and closes to reveal another texture. As a curtain in a window, the textile's perforations could be programmed to close in response to bright sun, providing necessary shading, and to open when a cloud passes. The textiles seem to breathe, like gills in the water, with textures and patterns that are both functional and poetic.

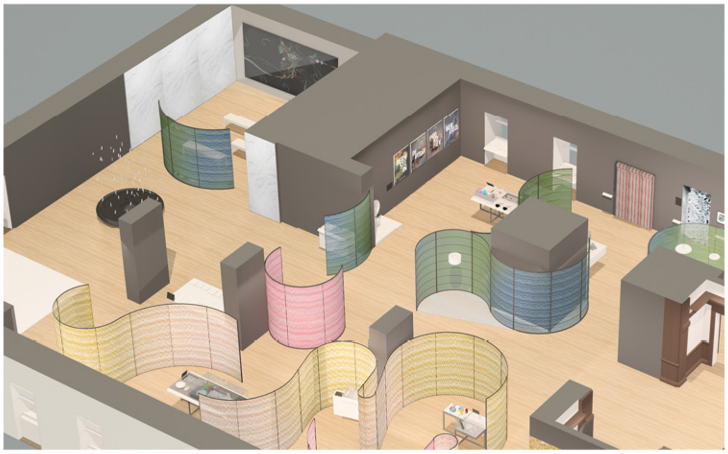
Materiality invites an embodied response, influencing how we interact with something. We bristle away from a porcupine's quills. We stroke a cat's long fur and pat a dog's matte hair. We sit erect in hard plastic chairs and slump and curl ourselves in the cushioned support of couches. Touch provides a universal interface, guiding our gestures and interactions. For Roos Meerman, tactility humanizes our interaction with technology. She designs tactile interfaces whose materiality invites desired gestures, rather than instructing users to wave or flap their arms in front of a screen. The Tactile Orchestra is an installation she created with KunstLAB Arnhem. In it, users stroke a wall covered in a furry material to control the intensity and instruments of a musical composition. The "furriness" directs the interaction. As Meerman tells us, "almost everyone approaches something furry with the same response. They want to stroke it."[7]

For the *Senses* exhibition, Cooper Hewitt invited Meerman to create a new version of her Tactile Orchestra installation. Synthetic fur covers a wall that is curved to undulate like a wave. Users stroke and sweep the fur with their hands, arms, and bodies, activating a piece of a musical composition that plays from binaural speakers overhead. The music is composed of string instruments. As Meerman explains, the string instruments more closely align with the act of stroking than would, say, percussion instruments. The composition is divided into six sections, tuned to different parts of the wall. When a user strokes one section of the wall, the strings programmed to that section play. When another participant touches the wall, strings in their section are added to the composition, which both participants hear. Multiple users are needed to "play" the full composition, suggestive of the orchestra itself. Meerman leverages our embodied response to material.

A young girl with a blond pony tail strokes a wall covered with dark fur.

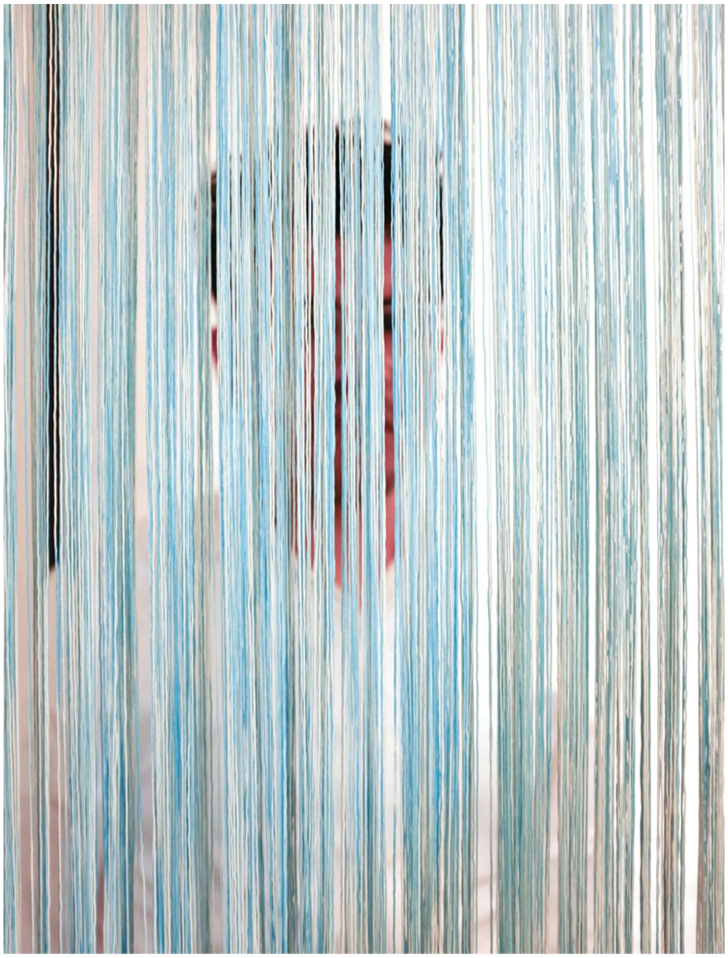
TACTILE ORCHESTRA, 2015; Roos Meerman (Dutch, b. 1991), Studio Roos Meerman (Arnhem, Netherlands, founded 2014) with Stefanie Hesseling (Dutch, b. 1985), Tom Kortbeek (Dutch, b. 1987) and Tim Rouschop (Dutch, b. 1988), KunstLAB Arnhem (Arnhem, Netherlands, founded 2014); Textiles, wood, electronics; 460 x 230 cm (15 ft. × 7 ft. 6 in.); © Xandravander Eijk

Materials are the flesh and bones of objects and buildings. Glass, wood, and silicone breathe, shift, and sigh. A curtain or bench absorbs sound. Light bounces, reflects, and floods the periphery —light is not a thing, but it changes everything. Textures speak to the eye as well as to the hand, incising flat surfaces with real or imaginary depth where the restless gaze can wander. Sensory design considers materiality across multiple dimensions, from the visible to beyond.



Two renderings show a museum, one from above and one down a long vantage point. Curving transparent walls wind through the space.

EXHIBITION DESIGN FOR THE SENSES: DESIGN BEYOND VISION, Cooper Hewitt, Smithsonian Design Museum, New York, 2017; Studio Joseph; Curtain made from Bolon fibers



A face is visible through a curtain made of pale blue and gray threads.
STUDIO JOSEPH'S EXHIBITION DESIGN for Cooper Hewitt's exhibtion *The Senses* features curving transparent partitions woven from colored strands of nylon fiber. The fiber is manufactured by Bolon for use in floor and wallcoverings. Throughout the exhibition, rich textures form the interface between people and objects.

Designing with Light

Rich Brilliant Willing

No aspect of an interior more powerfully shapes our sense of well-being than quality of light. In a restaurant or hotel lobby, a warm, welcoming light puts us at ease. In the workplace, light sets the tone of our day, lifting the mood and inspiring productivity. At home, light enlivens mealtimes, morning routines, and the moments we spend with friends.

Despite its constant presence, light is notoriously difficult to describe. Our perception of light is relative, rather than absolute, and so while we can easily measure the universal qualities of light itself, our individual physiological functions challenge our understanding and ability to articulate our experiences. A number of factors influence what we see, including the contrast of light against its environment. The amount of light emitted by a small lamp, for example, appears much brighter at night than in the light of day. Additionally, the adaptive physiology that allows our to eyes adjust quickly to the dark also complicates our perceptions. Designing an environment with a desired sense of atmosphere, therefore, requires the consideration of light's quantifiable and perceptual qualities.

THINKING ABOUT LIGHT

// Envision your space with light before considering fixtures. Which surfaces should draw attention? Which should recede? Where is the visual focus?

// Apply layers of light: an overall or ambient layer for comfort, focal lighting on important objects, and decorative elements that add sparkle and depth. Avoid bland, uniformly lit spaces.

// Light selectively, placing light where it's needed and minimizing it elsewhere.

// We see by contrast. In a softly lit environment, a little light can do a lot of good.

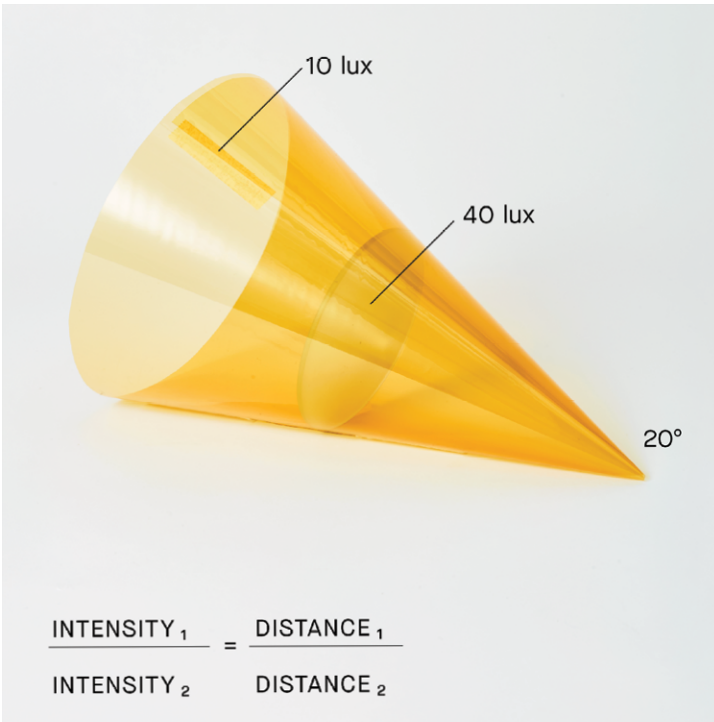
// Distribute light around the space; avoid concentrating all the lumens in one place. It is more comfortable—and more effective—to have multiple "points of light" than a few very bright fixtures.

// Adjust the quantity light with dimming controls. This will help in balancing brightness around the space and adapting the lighting for different activities and users.

Light: How Much Is Enough?

Light is measured in several ways, including the amount of light at the source and the amount of light arriving on a given surface. In the International System of Units (the modern form of the metric system), the amount of light at the source is the lumen. The lumen is often incorrectly confused with the watt, a measurement traditionally stamped on incandescent lightbulbs indicating the amount of energy consumed. More efficient contemporary light sources, including the LED, consume fewer watts yet yield more lumens.

Looking beyond measurements alone, an effective designer takes into account the human experience. These myriad considerations include intended application, desired ambiance, and the materiality of surfaces as well as age of users. In the realm of architecture and interior design, our innate inability to describe light poses an extra obstacle.



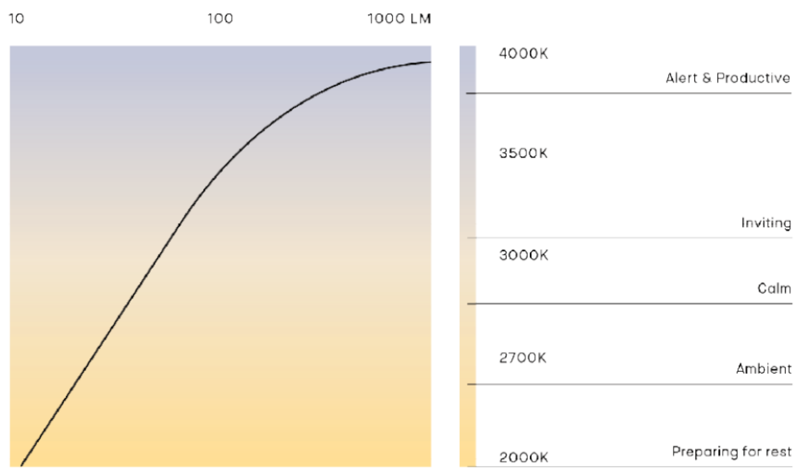
A 20º beam of light is represented by a cone. If the source were 100 lumens, then at a 5-meter distance, the amount light arriving at the surface would be 40 lux.

INVERSE SQUARE LAW The lux is the unit of measure for the amount of light on a given surface in lumens per square meter. According to the Inverse Square Law, to find the lux at **E1, E1=(d1/d2)^2*E2**. Doubling the distance between source to surface reduces the lux by (2)^2, or 4 times. Practically speaking, a larger room therefore requires more light.

A Whiter Shade of Pale

There are typically two reasons why someone would proclaim to dislike a certain type of light. Both reasons relate to colorimetry, the science of color perception. Sometimes light seems too cold in appearance, with a blueish cast. Other times, it appears too warm and yellow. The apparent color of light is described with Correlated Color Temperature (CCT).

The standard CCT unit of measure is the Kelvin. The warm yellows of a match flame measure around 2000K, and the clear daylight of a bright blue sky measures upwards of 10,000K. Counterintuitively, warm colors have lower temperatures than cool ones. Ideal color temperatures match the intended purpose of a space. Cooler colors function well to promote a sense of alertness, and we tend to expect these environments to be brighter. The inviting, tactile quality of warmer colors fits more intimate settings, which tend toward lower light levels.



THINKING ABOUT LIGHT

// Color consistency among fixtures is important. Similar fixtures should look the same.

// Color temperature varies over the course of the day, influencing the activities and mood of a space.

// Dynamic color temperature is a feature of some LED products. Look for user friendly features such as Warm Dim or Dim to Warm. These LEDs get warmer as they dim, unlike standard LEDs, which get cooler when dimmed. Professional products such as Tunable White or Natural Light have more expansive and complex variables

// Color temperature influences the appearance of interiors, finishes, and fabrics: cool light favors blues, greens, silver and gray; warm light favors reds, yellows, wood, leather, gold, and bronze.

THINKING ABOUT LIGHT

// Not all spaces will necessitate high color fidelity.

// Small differences in CRI values are generally unimportant, and values above 85 are typically acceptable.

// When choosing a source or fixture, select the appropriate color temperature first, then consider color rendering.

// For pleasing facial tones, choose light sources rich in red and evaluate the source on your hands or face.

// For specialized applications where color is critical, use the TM-30 metric to evaluate options.

The Art of Fidelity

We count on the ability of light to produce expected and natural colors, such as skin tones or the appearance of fruits and vegetables. Deviation from naturalness, or a lack of fidelity, is a measurable characteristic of light.

The invention of the fluorescent bulb, infamous for casting skin tones in greenish, sickly hues, also gave rise to a testing method to address the hue shift and saturation of color caused by these new lamps. The CRI, or Color Rendering Index, was established in the 1960s to measure a light source's accuracy when illuminating an object against a specific benchmark: the incandescent bulb. The range of values was arbitrarily set so that the maximum CRI would produce a score of 100, and a warm white fluorescent would produce a score of 50.

Today's technologies (including LED and incandescent enhanced with neodymium) offer a wider, more saturated range of color. The aisles of many grocery stores likely offer greener bell peppers and redder steaks because the lighting has been designed to produce higher saturation of these specific colors. The resulting CRI scores of such highly saturated light sources are inherently lower than 100. CRI values above 85 are generally acceptable, and it is important to point out that higher scores do not necessarily correspond with greater preference in the general population.

CRI testing today is achieved by comparing fourteen color chips (R1 to R14) to a reference source of the same color temperature. A score of 100 indicates a perfect match to the original benchmark, the colors as produced by an incandescent bulb.

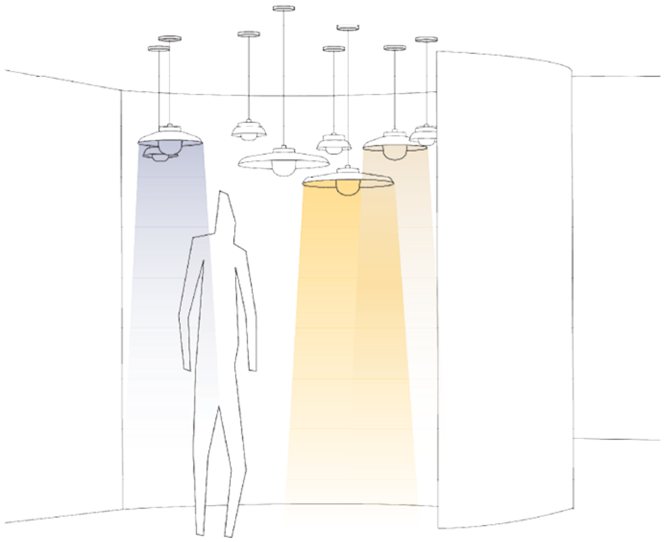
There are two faults in the score. One lies in the benchmark itself — who is to say a limited set of fourteen swatches and the incandescent bulb represent colors optimally? The second fault is that a single metric score oversimplifies, combining saturation and hue shift.

TM-30-15, launched in 2015, is a more nuanced system of measuring and communicating color rendition. It measures fidelity against an expanded rubric of 99 color samples and presents results in a graphical form to describe hue shift and saturation that the CRI system fails to address.

QUALITY & FIDELITY The Color Rendering Index, established in the 1960s after the introduction of fluorescent bulbs, uses 14 chips to measure fidelity **(RIGHT)**. The new TM-30-15 system **(LEFT)** employs 99 color samples.

In Living Color

Rich Brilliant Willing is a studio founded on the idea that light is an experience and an essential component of effective architecture and interior design. Light's many variables — its intensity, color, and fidelity — can subtly or dramatically alter the atmospheric qualities of a space. In turn, light affects our sense of well-being, productivity, and mood. For many people, however, these nuances go unnoticed.



A figure stands beneath a group of round hanging lighting fixtures. Light shining from one of the fixtures is cool; from the other fixtures it is warm.

ADAPTIVE LIGHTING Sensors embedded in the installation react to visitors. Meanwhile, the visitor's visual perception adapts to the changing lighting conditions. Lighting Fixtures, In Living Color, 2018; Rich Brilliant Willing (New York, New York, USA, founded 2009); Light-emitting diodes, aluminum, glass; 15.2 x 182.9 × 15.2 cm (6 x 72 x 6 in.); Courtesy of Rich Brilliant Willing

In order to recast light from the background of our perceptions to the foreground, RBW created the installation In Living Color for Cooper Hewitt's exhibition *The Senses*. This interactive installation emphasizes light's effects on our environment.

As visitors move below a series of light fixtures suspended from the ceiling, the fixtures respond to people's motion by changing in temperature and intensity, triggering a change in the atmosphere of the surrounding environment. Like the hiss of a background white noise that disappears with time, light is an ambient sensory detail that we rarely notice in our environment after we adapt to its baseline. When the white noise abruptly changes, however, the background in our environment becomes acutely apparent.