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Editorial

Visual perception of materials: The science of stuff

Until relatively recently, the perception of materials and their properties received barely any attention. There was, of course, research on 'surface properties', such as the large body of investigations of color and lightness constancy; some occasional observations on transparency and scission (von Helmholtz, 1867/1962; Hering, 1874/1964; Katz, 1935; Kanizsa, 1955; Metelli, 1974; Beck, 1972, 1978; Beck & Ivry, 1988; Gerbino, Stultiens, & De Weert, 1990; Masin, 1997; D'Zmura et al., 1997; Anderson, 1997, 2005; D'Zmura, Rinner, & Gegenfurtner, 2000; Singh & Anderson, 2002); a trickle of articles on highlights, lustre and glossiness (von Helmholtz, 1867/1962; Hering, 1874/1964; Beck, 1972; Beck & Prazdny, 1981; Blake & Bülthoff, 1990; Nishida & Shinya, 1998); and some pragmatic attempts to characterize surface appearance for industrial applications (e.g., Hunter, 1975). However, few if any studies addressed the more general question of how we perceive, distinguish and represent the enormous variety of materials we experience in everyday life, such as soil, dough, soap and leather, along with their distinct physical and functional properties. Moreover, there was until recently little sense of a 'scientific community' within the broader field of perceptual research dedicated to the specific issues of material perception, a community with its own questions, methods, or theoretical controversies.

However, over the last decade or so, material perception has blossomed into something of a hot topic. There are regular symposia and workshops on material perception, and sessions dedicated to the theme at conferences like the Vision Sciences Society annual meeting. At least two major networks on the topic have been funded in Europe ("PRISM: The Perceptual Representation of Illumination, Shape and Materials") and Japan ('*Shitsukan*: Integrative studies of neural mechanisms and advanced information technologies for perception of material and surface qualities'). Thus, there is a new generation of researchers currently being trained, who treat material perception as their core topic of interest.

The nudge that can plausibly lay claim to setting this field into motion was Ted Adelson's (2001) conference paper entitled "On Seeing Stuff: The Perception of Materials by Humans and Machines". In that article, Adelson points out the disproportionate interest that human and machine vision researchers have paid to the perception and recognition of objects ('things') rather than materials ('stuff'). Things are the discrete, bounded, cohesive chunks of familiar matter that we readily recognize, like pens, telephones, or donkeys. By contrast, stuff is the unbounded, often mutable powders, slimes and textures of this world, which had not received anything like as much attention. Psychology has a long history of parsing the world into things and their psychological counterparts. Indeed, the study of things and their properties has permeated practically all aspects of perception and visual cognition: from object recognition to category learning; from object permanence in developmental studies to object-based attention in studies of normal adults and patient populations. Psychological 'objects' are seen as the outcome of putative feature integration processes that bind features together into discrete parcels with distinct identities. Visual segmentation processes are thought to chunk the retinal image into bounded units that are joined together by grouping processes into meaningful objects. We can track the movement of such objects, even when they disappear from the image due to occlusion or camouflage. We have an intuitive sense of persistent object identity that can withstand changes in the object's properties such as shape or color over time and space. Such objects also map intuitively onto the count nouns of language ('shoe', 'chair', 'rhinoceros', 'idea'), forming a thread that extends from perception into thought, memory, speech and action.

By contrast, the perceptual counterpart of stuff might be the statistical soup of pre-attentive features at the early stages of visual processing. Stuff (in the mind at least), is the texture-like jumble of basic image measurements that are coalesced by attention into discrete identifiable wholes. Stuff is represented in language by the non-count nouns ('snow', 'tea', 'velvet', 'anger'), i.e., the concept of an entity that does not have a discrete quantity which can be divided into smaller or larger amounts of the same basic essence. Nevertheless, despite the obvious intuitive importance of stuff to perceptual psychology, until quite recently very little attention has been paid to how the brain identifies and represents the physical stuff that is actually out there in our world: the peanut-butter, satin, brass or lacquer that permeate our daily experiences. These materials have distinctive appearances and distinctive typical behaviors, often with strongly associated affective responses, and predictable multisensory qualities. In short, materials have a distinctive 'look and feel', which determines how we can interact with them, whether they afford being eaten, used for cleaning or clothing or for gluing other stuff together. Without touching a material we usually have a clear impression of what it would feel like if we were to touch it: whether it would be hard or soft, slimy or gooey, flexible or friable, wet or dry. This helps us to work out whether the ground is safe to stand on or whether food is fit to eat. And industrial designers invest enormous time and effort into getting the *shitsukan* qualities of their products – their 'look and feel' – just right. It is material perception that makes pearls precious and advanced car paint technology into a highly profitable business.

This special issue is the first of two issues dedicated to providing a snapshot of current findings as material perception research develops into a mature, often interdisciplinary field, spanning

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human perception research and machine vision, optics, computer graphics, neuroscience and industrial design. This issue includes contributions ranging from investigations of basic cues to specific material properties and effects, such as gloss, viscosity and wetness; through multi- and supra-sensory representations of materials and their properties; to neural underpinnings of material perception processes in the brain. The articles include applied as well as basic research, such as the development of display technologies for realistic interactive visualization of surface qualities. There is even a study of material perception through echolocation in blind participants. Together, these articles hint at the wide gamut of domains for which material perception is relevant, from making judgments about the physical stability of objects to recognizing and categorizing specific materials. The articles cover cues from haptics and audition as well as vision, both static and in motion, varying in complex ways over space and time. The more we learn about material processing at both psychological and neural levels, the clearer it becomes how complex the perception, recognition and classification of materials truly is.

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