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Reviews

Structural information theory: The simplicity of visual form by E Leeuwenberg, P A van der Helm; Cambridge University Press, Cambridge, 2013, 333 pages, £74.99 cloth (US $119.99)
ISBN 9781107029606.
Simplicity in vision: A multidisciplinary account of perceptual organization by P A van der Helm; Cambridge University Press, Cambridge, 2014, 424 pages, £65.00 cloth (US $99.00)
ISBN 9781107034341.

General introduction. In the slipstream of the many publications surrounding the centennial anniversary of gestalt psychology (100 years after Wertheimer's landmark paper in 1912), Cambridge University Press published two books authored by two of the proponents who kept some of the ideas of gestalt psychology alive, in a period when its popularity had declined so much that it was almost declared dead. Both books, the first coauthored by Emanuel Leeuwenberg and Peter van der Helm and the second written by van der Helm on his own, represent a somewhat unconventional approach to one of the core principles of gestalt thinking—the simplicity principle; that is, the idea that the visual system organizes its visual world as simply as possible on the basis of the available information. In gestalt theory this principle was also known as the law of Prägnanz, conjectured to underlie all specific laws of perceptual organization (Wertheimer, 1923). Koffka (1935, page 138) specified Prägnanz as "goodness of form" when he wrote: "Of several geometrically possible organizations that one will actually occur which possesses the best, the most stable shape." More generally, gestalts were assumed to result from global field forces that lead to the simplest possible organization or minimum solution, given the available stimulation. From the very beginning, the simplicity or minimum principle was formulated in opposition to the likelihood principle by Helmholtz; that is, the idea that the visual system interprets the incoming proximal stimuli in terms of their most likely distal source.

In order to be able to derive quantitative predictions from the simplicity or minimum principle, one needs a formal theory to compute the complexity (or cost) of alternative perceptual descriptions. On the basis of ideas from information theory, which became popular in psychology in the 1950s and 1960s, Leeuwenberg (1969, 1971) initiated structural information theory (SIT) as a coding model to describe visual (and other) patterns as sequences of symbols, which can then be reduced to their simplest descriptive codes; that is, codes which specify stimulus organizations by capturing a maximum of regularity. The idea is then, simply, that the visual system selects the organization with the shortest code (the smallest information load). With the help of a number of colleagues (eg Boselie, Buffart, Calis, Povel) and students (eg Collard, Mens, Scharroo, van der Helm, van Leeuwen, van Lier, van Tuijl), SIT was developed further into a more general theory of perceptual organization, applied to a large number of specific cases (eg form, perceptual ambiguity, amodal completion, neon color spreading, serial pattern production and completion, priming and masking of part–whole relationships, symmetry detection). As a result, SIT was considered "the best-defined and most successful extension of Gestalt ideas" (Palmer, 1999, page 406). van der Helm, a mathematician who obtained his PhD under the supervision of Leeuwenberg, was the collaborator in this group who has been most successful in providing further theoretical foundations to SIT and expanding it beyond a mere coding model.

With these two books, Leeuwenberg and van der Helm have crystallized their thinking on simplicity and perceptual organization after several decades of development, refinement, expansion, and deepening. Of course, these books must be read by those who are interested in simplicity, form, and perceptual organization and, as I will argue below, also by those who want to gain a deeper insight into some of the most fundamental theoretical questions in vision.

Structural information theory

The first book is focused on SIT and its application to form. It stays relatively close to Leeuwenberg's work. Part I provides the building blocks towards a theory of visual form, discussing its constraints and attributes, models and principles, assumptions and foundations. It also discusses the role of process versus representation in perception theories—one of the central issues of debate surrounding SIT.

Specifically, when SIT proposes that the perceived organization is the simplest one, it refers to the preferred pattern representation amongst all possible pattern representations. Hence, it employs a representation criterion, not a process criterion. It is theoretically agnostic (silent) about the underlying processes. Opponents have always argued that this reduces it to a mere methodological tool to generate and test predictions, excluding it from the realm of perceptual theories. Leeuwenberg and van der Helm defend their position by arguing for the primacy of representations. In their view, objects are the output of perception, not the input: "The goal of perception is not to establish properties of given objects but to establish objects from properties of the given retinal image" (page 1). With this view, they position themselves in the phenomenological tradition that characterizes the gestalt approach (eg Albertazzi, in press; Koenderink, in press), but which has been almost completely suppressed in contemporary work on perceptual organization within mainstream vision science (dominated by the computational tradition à la Marr) and visual neuroscience (dominated by the linear systems approach). One can regret that Leeuwenberg has never made a serious attempt to relate his approach to the mainstream approach, because the impact of SIT could have been much stronger if he had, but the philosophical position he takes is one that can be defended. In addition, from a researcher's point of view, one can also justify this choice as a valid methodological stance: it is better to start perception research from what is most accessible (perceptual interpretations, phenomenal experiences) than from raw sensations (unstructured patches of stimulation at the retina, which are probably fundamentally inaccessible to conscious experience) and from the perceptual processes (which are too rapid and effortless to leave traces in experience).

Part II discusses the formal coding model and how it can be turned into a perceptual coding manual for line drawings, surfaces, and objects. It then discusses specific applications to explain (describe, predict) preference effects (occlusion, transparency, rivalry), time effects (perceived temporal order, perceived simultaneity), and hierarchy effects (superstructure dominance, mental rotation, reference frame effects). This part is probably the most relevant one for readers who want to understand how SIT works in practice. It discusses a large number of empirical studies in which SIT has been applied successfully. In this sense, this part also provides the necessary background to evaluate SIT's empirical scope, predictive success, and explanatory value. The applications which I personally found most inspiring are the ones on superstructure dominance (especially in relation to Navon's work on global precedence and Biederman's recognition-by-components theory) and nonaccidental properties (especially because it provides a clear test case for the theoretical dispute between simplicity and likelihood).

Part III presents some interesting extensions. In the chapter titled "Perception beyond SIT" the authors discuss the role of metrical information (which normally falls outside SIT's focus on structural information) and the issue of handedness; that is, how the visual system is able to distinguish an image from its mirror reflection—one of Leeuwenberg's last pet topics. In the chapter titled "SIT beyond perception" the authors discuss extrapolation of alphabetic letter series and evaluative pattern qualities such as distinctiveness (with implications for visual search and visual memory) and interestingness (including how beauty relates to goodness).

The first book is a well-written, well-structured overview of SIT at the endpoint of its development. The underlying (meta)theoretical principles and assumptions are spelled out clearly. The empirical support is reviewed in just enough detail to understand all the necessary details. The systematic and coherent presentation of this material makes it relatively easy to digest. The different sections and chapters contain useful previews and interim summaries. The book has a large number of richly detailed coding examples as well as many visual examples, with Leeuwenberg's personal touch (in addition to having a keen eye as a visual phenomenologist, he is also very talented in drawing and painting). And yet, in spite of these obvious qualities, I worry that it will not lead many researchers to use SIT as a basis of their own theoretical and empirical work as the approach taken seems somewhat too detached from mainstream vision science (eg the reference list is strongly biased to the authors' own work and slightly outdated). This predicted limited impact is unfortunate, because there is a lot to be learned from this approach. I very much enjoyed reading this book, and the margins of my annotated copy are full of exclamation marks and notes that require further thinking.

Simplicity in vision

The second book is much broader, discussing the role of simplicity in vision at a much deeper theoretical level and expanding the realm of SIT as a multidisciplinary account of perceptual organization.

The book has a prologue in which three kinds of levels are distinguished: first, the well-known distinction between low, middle, and high levels of vision, here characterized as dealing with feature extraction from retinotopic images, perceptual organization (ie binding selected features into integrated percepts), and everyday interactions between perceptual organization and higher cognitive faculties; second, Marr's well-known distinction between the computational, the algorithmic, and the implementational levels of description. Third, and less well known, is the distinction between three levels at which theories (general sets of conceptual ideas) and models (more specific versions of the theoretical ideas that can be tested on predictive power and practical feasibility) can be evaluated: the theoretical cycle (centered on formalizations, rooted in mathematics), the empirical cycle (centered on experiments, rooted in physics), and the tractability cycle (centered on implementations, rooted in computer science). This prologue sets the stage for what follows, because the book has three major parts—one for each of these cycles. Each part has two chapters. The book ends with an epilogue towards a gestalt of perceptual organization.

Part I on the theoretical cycle has a chapter on visual information processing and one on veridicality by simplicity. In the first chapter van der Helm offers some general considerations and a succinct summary of SIT. In the second he discusses the theoretical controversy between the simplicity and likelihood principles and proposes a new kind of synthesis, not in the form of a unification but in the form of a juxtaposition between maximizing certainty and minimizing information (formulating one in terms of the other; see figures 2.12 and 2.13 on pages 84 and 86). This chapter deepens the earlier debate between Feldman (2009) and van der Helm (2011). Although it will probably not convince the adherents of the currently dominant Bayesian approach, the chapter does provide interesting historical material about classic (eg Morse, Nyquist, Hartley, Shannon) and modern information theory (eg Kolmogorov, Solomonoff, Rissanen), as well as fully spelled out equations and nice visual examples and diagrams. It certainly makes it easier to understand what the issues are in relating simplicity to likelihood, and vice versa.

Part II on the empirical cycle has a chapter on transparent holographic regularity and one on symmetry perception. The first chapter provides a theoretical foundation to the coding rules applied by SIT. By relating them to the nature of visual regularities, the so-called ISA-coding rules (iteration, symmetry, and two kinds of alternation) become instantiations of the fundamental principles of holographic regularity and transparent hierarchy. This section (pages 141–168) is pretty dense but theoretically very important. It is a self-contained, crystallized version of earlier work (van der Helm & Leeuwenberg, 1991), which has lifted SIT from a coding model to a theory of visual regularities. The second chapter is a further specification of this theory with regards to symmetry perception. Here, van der Helm discusses how the holographic approach is able to explain why some visual regularities are more salient (easier to detect, more robust to noise) than others. He responds to earlier criticisms by others and integrates more recent empirical work by his own students (Csatho, van der Vloed, Treder).

Part III on the tractability cycle has a chapter on transparallel processing (ie a form of processing in which items are processed simultaneously by one processor) and one on synchronization. The first chapter expands van der Helm's (2004) earlier process model of perceptual organization, which computes the simplest hierarchical organizations of strings (as prescribed by the theory of holographic regularity) with an actual algorithm that allows for transparallel processing by hyperstrings (ie the coding algorithm PISA, for parameter load plus ISA-rules). This is another dense section (pages 256–286), which requires some understanding of graph theory (provided in text boxes and diagrams). van der Helm then explains how this algorithm can be regarded as a neurally plausible combination of feedforward feature extraction, horizontal feature binding, and recurrent feature selection (see figure 5.2 on page 262), linking his own work to currently fashionable ways of thinking about cortical information processing. He also speculates how this algorithm has the potential to realize the power of quantum computing. In the second chapter van der Helm proposes that neuronal synchronization (another recent concept from neuroscience) can be regarded as a manifestation of transparallel processing discussed in the preceding chapter. He also proposes some kind of synthesis between representational theories like SIT and the theory of holographic regularity, on the one hand, and connectionism and dynamical systems

theory, on the other hand. Specifically, he sketches a kind of flexible cognitive architecture consisting of hierarchies of transient neural assemblies called 'gnosons'. Clearly, these last two chapters are the most speculative ones of the whole book, especially regarding the neural mechanisms.

Taken together, the three parts of the book provide a coherent and deep underpinning of the role of simplicity in vision. Indeed, as highlighted in the epilogue, it attempts to offer a gestalt of perceptual organization in the sense of the whole being more than the sum of the parts. It is broad but at the same time focused on the problem of perceptual organization in pattern, form, and shape perception. It ignores color, depth, and motion perception. It is theoretically deep but at the same time it does not pretend to offer a 'grand unified theory' of vision. The building blocks provided in the six main chapters remain relatively separate subtheories. Although they do get a place at the intersections between the three interlocked cycles of research (see figure E.1 on page 346), the kind of integration that is offered remains at a relatively abstract, almost metatheoretical level. Indeed, as the author himself acknowledges, theorizing is a kind of storytelling. The present story is a very general one, and much room has been left to readers/listeners to fill in the gaps using their own imagination. In developing this broad theoretical framework, van der Helm integrates ideas from experimental psychology, cognitive science, artificial intelligence, computer science, mathematics, neuroscience, evolutionary biology, and philosophy of science. So, the book is truly *multi*disciplinary; but to become truly *inter*disciplinary, the theories would have to be fleshed out in detail in specific models, implemented in computational algorithms, neural networks, or dynamical systems, and thoroughly tested in all of their psychological and neural aspects. This would require several years of work by a team of specialists in each of the disciplines involved, all collaborating within the same coherent framework and research program. Unfortunately, the current intellectual climate is not supportive of such endeavors of medium-sized scale, duration, and focus, falling in the cracks between normally funded research projects of single labs and megalomaniac enterprises like the Human Brain Project.

General discussion. As should be clear from the above reviews, the two books are nicely complementary. The first is focused and self-contained. The second is unashamedly broad and visionary. Because of this, their styles are rather different, although the concepts and examples they use are often the same. Both books are well written, although they do require effort from the reader. In the first book the difficulty results from the level of detail (eg coding examples), in the second from the level of abstraction. I can imagine that some readers find the level of structuring (especially in the second book) excessive, even to the extent that several passages are formally constructed as complete parallelisms or juxtapositions in word choice and grammar. These style issues aside, the two books are sufficiently different in focus and scope, while at the same time being sufficiently intertwined to form a beautifully balanced pair. Besides their theoretical and empirical common ground, the actual overlap in text, figures, and references is minimal.

I strongly recommend this pair of books to everyone working on perceptual organization and to all vision scientists and neuroscientists who believe, as I do, that gestalt formation is the key thing the brain does. I promise to everyone taking the time to read it seriously and to think about it deeply that it will provide new inspiration and a refreshing expedition outside the comfortable cocoon of mainstream thinking.

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Psychology of touch and blindness by M A Heller, E Gentaz; Psychology Press, New York, 2014, 284 pages, $150.00 cloth, $59.95 paper, ISBN 9781848729452

There is a tendency to think of touch as a 'minor' sense, less sophisticated and less important than vision. Certainly, as a research topic it has received far less attention. In *Psychology of Touch and Blindness*, however, Morton Heller and Edouard Gentaz demonstrate that touch is both interesting and important. As the title makes clear, a large portion of the book is concerned with the relevance of this sense for blind people, but the authors make a strong case that research into touch also significantly benefits the sighted.

In the introduction the authors set out the book's topic, pointing out the uniqueness of the touch organ, which changes shape in response to its stimulus. They discuss the importance of this sense, referring to the case of a person who suffered a total loss of tactile perception, and the devastating nature of this blow. In this first chapter the authors also introduce the topics covered in the book, and provide some historical and philosophical background for the research area. One idea which is discussed here is Gibson's ecological psychology, which contests the validity of results obtained in restricted laboratory trials, where participants are tested under abnormal settings. The 'ecological perspective' is subsequently referred to at several points throughout the book. For example, the authors consider the consequences of restricting participants' hand movements during haptic exploration.

From this relatively easy-going first chapter, the book dives into the neuroscience of touch perception. Having no background in the subject, I admit that I struggled here; but whilst I did not take away much from the bulk of the chapter, its conclusion was much easier for me to follow. This turns out to be a common feature in the book, which I will return to later.

After this dedicated chapter on neuroscience, the remainder of the book mainly discusses results from experimental psychology, as well as social science, particularly education. The next few chapters focus on the psychology of haptic perception, looking first at perception of objects and their properties—such as shape, weight, temperature, and texture—and then at several tactile illusions. I found this chapter particularly stimulating. Several such illusions have been adapted from similar optical illusions, and the authors are particularly interested in comparing the two senses in this context. For example, in the Müller-Lyer illusion people tend to perceive a straight line as longer if it has inward-pointing arrows at its ends, rather than outward-pointing arrows. One hypothesis for this result, called the confusion model, suggests that the arrows make it harder to judge the length of the line and so the size of the whole diagram (which is greater with inward-pointing arrows) is measured in its place. The illusion is generally observed in touch as well as in vision, and some research indicates that the confusion model is valid in both cases.

In contrast, some other illusions reveal differences between vision and touch. In the horizontal–vertical illusion the height of an arch appears to be greater than its width, though the dimensions are identical. This illusion is certainly evident in vision, and also occurs in touch, though not to the same extent and most likely not for the same reasons. In vision the illusion is understood to occur due to an overestimation of verticals, added to an underestimation of horizontals. In touch, however, it is thought

that radial scanning is the underlying cause. That is, haptic exploration moving towards or away from the body takes longer than lateral exploration, leading to an overestimation of radial distances.

Chapter 5 deals with the interactions between different senses, notably between vision and touch. This is an important topic for the authors, and one in which they see a particular need for more research. Psychologists understandably prefer to consider a sense in isolation, often blindfolding and blocking out sound from participants during haptic tasks. This practice is problematic if you consider the ecological perspective, since it is unnatural—and sometimes distressing—to place participants in these conditions. Unfortunately, there is little alternative to this approach, since the relations between senses are complex and hard to disentangle. In some cases, for instance, vision complements touch. In others, vision may dominate and distract.

Although blindness is referred to throughout the book, there are several dedicated chapters on the subject. After a chapter on the development of haptic perception, chapter 7 provides a general introduction to blindness, covering the challenges faced by blind people in education and elsewhere. Road safety is of course an important problem, with the increasing abundance of roundabouts one of the more perilous examples. The use of visual imagery by blind people is also discussed, and the authors are particularly keen to tackle some common assumptions in this area. They are concerned that the belief that blind people are unable to visualise problems means that they will generally not be taught with visual reasoning tasks when they are young. This, added to the lack of confidence that arises from such assumptions—people tend to perform worse if they believe they are not good at something—could mean that inferiority in visual reasoning is a self-fulfilling prophecy. The authors look at this issue in more detail in the next chapter, and there follows a chapter on Braille and new technology aimed at blind people.

Chapter 10 discusses haptics in education, and finds that haptic exploration complements visual and auditory learning of letters in kindergarten children. Chapter 11 mentions various tactile interfaces, which are clearly beneficial to blind people, providing graphical user interfaces with computers, for example. They may also be useful for the sighted, however, as augmentation of visual input.

Throughout their book, Heller and Gentaz demonstrate a strong will to extract the most likely explanation from the relevant literature. For a given topic—a particular illusion, say—they will cite numerous studies and attempt to draw conclusions from various (often conflicting) results. In the body of the chapter these personal assessments tend to be fairly limited, with objective reporting making up the bulk of the content. However, each chapter ends with a conclusion in which the authors allow themselves more freedom to present their own interpretations of the evidence.

In fact, I found these concluding sections to be a particularly strong point of the book. There were several chapters whose topics I was unfamiliar with, and thus found harder to digest. In these cases it was very helpful to have the conclusions; more than just summaries, they are well written and engaging, providing a narrative which motivates the ideas discussed in the chapter.

Given the range of topics covered in this book, it is likely that many readers will not feel the need to read every chapter, but they might still benefit from reading the conclusions of the less relevant chapters. Perhaps the readers may even find that, having read the conclusion, they are then inclined to delve into the rest of the chapter. The concluding chapter fits this pattern, neatly drawing together the ideas found throughout the book, highlighting the issues Heller and Gentaz consider important, and outlining the areas where future research is most needed.

As an engineer working on a robotics project to do with touch perception, I benefited more from certain parts of this book than from others. Perhaps only one chapter (on the haptic perception of objects) was directly relevant to my research, and here I found the detailed and extensive analysis of the literature very useful. However, the quality of writing meant that I could engage with other parts of the book out of curiosity alone. For this reason I would recommend *Psychology of Touch and Blindness* to a wide range of scientists including psychologists, social scientists, neuroscientists, and engineers, but most certainly to anybody interested in *Perception*. It has enough detail to be of use to experts, and will certainly benefit those looking for an introduction into various aspects of touch perception and its relation to blindness.

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