

PREFACE

I recall that as I lay in my room with a migraine headache in December, 1958, an idea came to mind. There was, naturally, a certain period of time required for development of this idea, which accounts for the modest delay in bringing it to print, but here it sits before you now. In the interim, I have published a number of papers on the subject in the various journals. However, there are gaps between the papers and there is a body of knowledge that must be assimilated before these papers can even be read. With this book, I have tried to fill these gaps and provide the fundamental body of basic knowledge. The idea has matured through the years, so that my early papers on the subject now seem to me as quaint, primitive, and sometimes a trifle embarrassing. This book updates things.

I present here a theory of perception which is based upon the premise that a perceiver is necessary if there is to be a world external to this perceiver. Couched in other language, the existence of the world is relative, in some way, to the perceiver of that world. My debt to George Berkeley is supreme.

Taking this philosophy of perceptual relativity as a given, my first problem was to find a mathematical structure that would support it. After rather a lot of searching I did find a candidate for such a mathematical structure – one that did not dissolve in the next migraine – and my problem was then to test or validate it.

I chose the field of sensory science (neurophysiology and psychophysics) as a proving-ground because this field is replete with empirical equations – that is, equations that describe experiments, but which are without any known theoretical basis. If my candidate for mathematical structure was a good one, it should permit derivation, from this mathematical base, of all (or many) of the empirical equations of sensory science, and should provide a degree of conceptual unity to the field of sensory science.

Please notice that I have avoided using the term *mathematical model* for the structure in question. I have the feeling that a mathematical model is something created by the modeler, that he can modify to suit his desires. Like clay in the potter's hands. I have no such feelings with regard to the mathematical structure presented here. I feel more as if I have “unearthed” the structure or, at best, discovered it. It was there all along, and I just found it. It is not really mine to modify at my whim. It is too simple and too fundamental a concept.

For whom is this book intended? I think it is for those with a keen desire to understand what is meant by *perception* or *sensation* – not specifically *this* perceptual phenomenon or *that* sensory mechanism, but something closer to the fundamental nature of the perceptual process, the conscious apprehension of the world by a living (or non-living!) creature. But before you say to yourself “That’s me for sure!” (you would never say to yourself “That is I!”) you had better consider the overhead. If your background is largely in the physical sciences, is your desire powerful enough to impel you to study – not just read – the purely physiological and psychological chapters of this book before proceeding to the more physically oriented material? And if your background is in biology or psychology, are you prepared to take the time to brush up on, or learn *de novo*, the necessary basic mathematics? You don’t need a lot of mathematical knowledge to get through this book, but you do require at least one course on basic calculus and some introductory mathematical statistics. Experience has shown me that it is *absolutely mandatory*, for comprehension of this material, to understand (a) logarithms and exponentials, and (b) the Taylor series in one variable. With respect to the latter, you should be able to expand, for example, e^x or $\ln(1+x)$, $-1 < x \leq 1$, in a Taylor series. Not exactly higher mathematics, but at least that level is required to follow what is contained on these pages.

The book is intended for psychophysicists and physicists, for sensory physiologists, for engineers and computer scientists interested in perceptual phenomena, and for anyone with a desire to explore sensation and perception from a new perspective. The material in this book has formed part of a course given yearly to senior undergraduates in the Department of Physiology, and to students in the School of Graduate Studies at the University of Toronto. Among the offerings of this book are explanations of why both Fechner’s and Stevens’ laws are valid, to differing degrees, in different circumstances; why we can react more rapidly to a more intense stimulus; and how perception in the biological sense can be related to “quantum observation”, as expressed in quantum mechanics.

Chapter 1 provides some orientation. Chapter 2 introduces the *entropic theory of perception*, which, I hope, will encourage the reader to study the next six chapters of background material in depth. Chapters 3 to 8 provide background in sensory science, thermodynamics and statistical mechanics, and information theory. The reader may choose from these chapters to complement his or her background. For example, a physics major does not require my “crash course” in thermodynamics. While Chapter 3 provides basic sensory science, it is my experience that many sensory scientists are not too familiar with these quantitative aspects of their field. When fortified by the material in Chapters 3 to 8, the reader should find no difficulty with Chapter 9, where the fundamental equations of the entropic theory of perception are developed. My journal papers often *started* at the level of Chapter 9, making the assumption that the reader could provide the necessary background.

Chapters 10 to 14 are heavily numerical, providing the experimental testing of the theory. No act of faith is required on the part of the reader to accept the validity of the theory that has been developed. Scores of experimental records and graphs are presented in the book. The reader, armed only with a pocket calculator, can confirm or deny the capability of the theory to explain the data. Predictions are also made which transcend the available data.

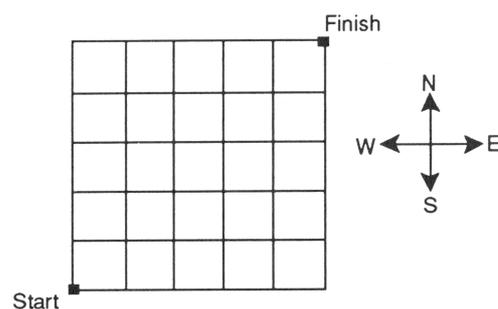
Fundamentally, I present here a single equation, $F = kH$, and a mathematical structure for H . It is demonstrated that from this single equation follow most of the empirical equations of psychophysics. I entreat the reader to judge the equation not on its ability to generate any one sensory law, such as Fechner’s law or the power law of sensation, which might be improved by the *ad hoc* addition of terms, but by the totality of its capabilities – the ability of a single equation to accomplish multiple tasks.

A parallel theme, begun later in the book, is the development of the *perceptual unit*, a structure that can, *of itself*, perceive, or be aware. The approach taken here is, in a sense, complementary to that of the neural network modelers. In the latter approach, it is hoped that higher mental functions may emerge from the interplay of a large number of very simple units. In the former, entropic approach, the germ of higher mental function is encapsulated in a single perceptual unit

Chapters 15 and 16 give the history of development of the entropic idea. That is, chronologically, one would place these chapters as chapters 1 and 2. However, I wanted the reader to sample the power of $F = kH$ before learning of the origins of the idea. Chapter 17 is a flight of fancy. While it is easy to read as a stand-alone chapter since there are no equations, I fervently hope that my readers will not do so. The sole claim of this chapter is that *it issues from*, or is an extrapolation of, the more restricted form of the entropy theory which makes up the rest of the book, and which I have striven so hard to validate using experimental data. Only when the extent of validity of the core theory is established in the mind of the reader, can he or she attain the perspective from which to judge the merits of the extrapolations offered in the final chapter. Chapter 17 may provide material for fireside discussion, but the reader must not emerge from reading this book with the impression that it was about cochlear implants or Darwinian evolution. I invoked the metaphor of a dessert, which is last in a meal, but does not contain the greatest part of its nourishment.

The book deals with sensation *in general*, and not with any particular organ of sensation. It demonstrates how one may derive many of the mathematical laws of sensation *without reference to the mechanism of sensory transduction*. How is such a thing possible? Surely you have to know how the organ works before you can make a mathematical statement about its function! Not so. Laws of the “conservation” type, such as found in thermodynamics, permit one to formulate mathematical constraints without knowledge of specific mechanisms.

By way of analogy, consider a rectangular grid of streets as shown in the map below.



The grid is divided into 25 squares, representing city blocks. The north-south streets are all one-way streets leading north, and the east-west streets are all one-way streets leading east. An automobile begins at START and reaches its destination at FINISH.

(a) What distance was traversed by the automobile as it travelled from START to FINISH, without violating the one-way laws?

(b) What route was taken by the automobile as it travelled from START to FINISH?

Clearly the answer to (a) is 10 blocks, and the answer to (b) is unknown. We know the total distance covered (analogous to a conservation law), but we do not know the exact route (or “mechanism”). In the same way we shall be able to discover, to some degree, how a taste or light receptor responds to its specific stimulus by observing the total amount of information it receives from its stimulus (cf. total number of blocks travelled), but we may not be able to say anything about the anatomy or specific physiological mechanism of the receptor (cf. exact route taken by the automobile).

I am grateful to a number of my colleagues and students for their support and assistance in the writing of this book. Particular thanks to (mathematician) Beatrice Aebersold for proof-reading the first twelve chapters with special attention to mathematical accuracy. I am grateful to Professor Lawrence Ward for many discussions on the entropy theory, and for his insightful comments on the difficult Chapter 13. Especial thanks to (physicist) Willy Wong for his commentary on the quantum physical sections of this book, for his help in carrying out many of the curve-fits, and for assistance with the computer programming that was needed to prepare many of the diagrams. As always, the author bears full responsibility for the material as presented.

I am most grateful to the Natural Sciences and Engineering Research Council of Canada for their support of much of the research on the entropy theory of perception.