

ASPECTS OF MOTION PERCEPTION ★ KOLERS

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# ASPECTS OF MOTION PERCEPTION

BY

PAUL A. KOLERS



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FOR  
JULES V. COLEMAN  
AND  
GEORGE A. MILLER  
WHO MADE LIGHT OF DARKNESS

*Human vision is such an enormously rich complex of experiences, and human beings are so diversified in habits and interest, that no two of us value our eyes for quite the same set of reasons. If asked what aspect of vision means the most to them, a watchmaker may answer "acuity," a night flier, "sensitivity," and an artist, "color." But to the animals which invented the vertebrate eye, and hold the patents on most of the features of the human model, the visual registration of **movement** was of the greatest importance.*

G. L. WALLS (1963, p. 342)

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## FOREWORD

IN 1964 I published a paper that pointed to certain differences in the way the visual system implemented the perception of motion derived from physically moving objects, and illusory or apparent motion derived from flashing lights. The paper came to the notice of H. J. Eysenck, editor of the International Monograph Series in Experimental Psychology that is published by Pergamon Press. I accepted his invitation to prepare a monograph on the subject of apparent motion, but between that time and 1969 my attention was occupied by other things. At the latter date, at Bell Telephone Laboratories, I undertook the study of some aspects of motion and form perception, particularly as they relate to the quality and fidelity of electronically transmitted images. This monograph grew out of that study.

A number of problems confront the engineer interested in transmitting pictures electronically, because pictures tend to be quite detailed but the transmission medium is both limited and expensive. Hence a number of engineers actively explore the topic of bandwidth compression, seeking a means by which maximum amounts of visual information can be transmitted at minimum cost. It seemed to me that a contribution to this topic that a psychologist might make would be to study the kinds of information that people actually use in their perception of continuing sequences of briefly presented pictures, such as characterize television transmission of real scenes. Not everything in a picture is perceived, nor do people typically have to look at great amounts of detail in order to come away with an adequate representation of what they are being shown. The reason is that much of our perceiving is anticipatory and inferential; it is based on an active sampling of clues rather than on passive reception of details. What is not known, however, is whether the sampling is haphazard or whether it is rule-governed; whether, that is to say, any aspect of any object is as good a clue to its identity and is as likely to be sampled as any other. The

intuitive answer to this uncertainty is a negative one; and in this regard concepts of salient or distinguishing features that characterize objects and facilitate their identification have come to the fore in recent years. Hence we may ask, what aspects of pictures best aid their recognition; what features most readily aid in distinguishing them? What are, in fact, the salient or distinctive features of pictures? Can one formalize these characteristics?

Questions of this kind motivated some of the research I shall report later in this monograph. The direction followed in seeking an answer was the classical one of dealing with simple, stripped down instances of stimuli. Although the pictures most likely to be transmitted in an electronic system are of people in movement, we began with simpler instances; in fact, with such classically simple ones as plane geometric figures. Moreover, we studied their perceptibility not when they were presented one at a time, measured for their specific geometry and luminance, but when they were presented in brief sequences. Therefore we were immediately dealing with illusory motion of the configurations, for it is a characteristic of the visual system that it perceives brief, properly sequenced presentations as objects undergoing spatial translation. It is just this characteristic, in fact, that the motion-picture projector and the television screen take advantage of, albeit in substantially different ways, in triggering those perceptions of objects in motion that we do see with those media. As we shall see below, the technological successes with those media do not depend upon a correct understanding of their effects on the nervous system; the technology works, but no currently available account of the perceptibility of forms in motion is correct. Theory lags practice rather extensively in this domain.

One outcome of our research was the discovery that the visual system actively constructs, implements, and fills in features of objects derived from a sampling of the physical presentation. The visual system does not merely record what has been presented to it (if it records that at all); it actively creates its own pictorial reality. Moreover, the mechanisms underlying this creation seem to be substantially different from the mechanisms utilized in feature analysis. What role, if any, that feature analysis plays in normal perception is not entirely clear.

These facts emerged from a study I carried out with James R. Pomerantz in the fall and winter of 1969 and published in the *Journal*

*of Experimental Psychology* in 1971. Intrigued and puzzled by them, but under a deadline created by other forces, we followed through with this investigation during the early spring of 1970. Reminded by Pergamon Press of my commitment to do a monograph on apparent motion, I thought that these new investigations might be embedded in the context of this old problem; for the fact is that people have been looking at motion pictures for more than seventy years, and at television screens for more than twenty-five, but the mechanisms governing these perceptions are still unknown.

Regrettably, our work does not answer all of the questions it set out to answer. Indeed, we were blocked for some considerable time, for in our thinking we continued to seek positive answers to certain questions whereas it becomes increasingly likely that some of them cannot be answered positively. Thus for conceptual and administrative reasons it was not possible to round out this work, and it is incomplete. I present it at least for the questions it raises if not for the answers it provides.

On and off between 1964 and 1968 I discussed various aspects of the perception of illusory motion at Project Zero at the Harvard Graduate School of Education. I think it was in response to those beneficent challenges that some concern with pictorial notation crept into my own thinking, although whatever distortions it may have there are not to be laid at the door of Project Zero or its director, Professor Nelson Goodman. It was during that period also that I carried out some preliminary experiments on form and motion perception at the Research Laboratory of Electronics, in connection with a course on perception and cognition I taught in the Department of Electrical Engineering at Massachusetts Institute of Technology. Moreover, as my own command of German is poor, I am indebted to several friends and former colleagues for aid with various aspects of the older literature. In particular I thank the former Misses Katharine Gilbert and Jean Mechlowitz, and Dr. D. C. Milne in this connection. I also thank Drs. David N. Perkins, Ronald Cohen and Ivan Bodis-Wollner for their comments on the manuscript. My greatest obligation, however, is to James R. Pomerantz for his conscientious, creative, and energetic contributions to our short-lived collegiality. I am not sure that I would have had the patience or subtlety to pursue these elusive realities alone; indeed he always shared and sometimes even led in the formulation of our

experiments. And of course I shall forever remember my stay at Bell Telephone Laboratories, and here record my thanks to that institution for enabling me to carry out this research.

*Toronto, Ontario*

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## CHAPTER 1

### THE BACKGROUND

ABOUT 2500 years ago the mathematician and philosopher Zeno of Elea invented four puzzles regarding distance and motion which were, in Bertrand Russell's words, "immeasurably subtle and profound". The most famous of them, that the swift Achilles can never overtake a tortoise that has started a race before him, and indeed all of the other three, have finally given way before mathematical analysis (Russell, 1938, pp. 347-354; Grünbaum, 1967), but like a ghost in the machine, they still haunt proposals about the mechanisms of perception.

One interpretation of Zeno is that the perception of motion is based not on current sensory information, but on memory for position and time; hence on comparison, guess, or inference. This interpretation alleges that what our visual system actually detects are objects in different locations at different times; noting the disparity, we create a sense of motion to resolve it. Perception of objects, memory of their position, and delusion are therefore the main components, according to this theory, of our perception of motion.

Until the last quarter of the nineteenth century there was little evidence that refuted this view directly. Then, in 1875, the physiologist Sigmund Exner showed that when things are arranged properly, two brief but stationary flashes are seen as a single object in motion. The timing of events is so rapid moreover, and the perception of motion so immediate, that memory cannot be its source. Working at a time when the task of psychology was taken to be the identification of the sensory elements of perception, Exner argued that motion is not an inferred attribute of objects perceived in different places, but a basic element in the mind's armamentarium.

Aside from its philosophical implications, the import for psychology of Exner's study lies in its systematic use of what even at that time