EXCERPTED FROM

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A NEW KIND OF SCIENCE

SECTION 10.2

What Perception and Analysis Do

In the traditional sciences, it has rarely been thought necessary to discuss in any explicit kind of way the processes that are involved in perception and analysis. For in most cases all that one studies are rather simple features that can readily be extracted by very straightforward processes—and which can for example be described by just a few numbers or by a simple mathematical formula.

But as soon as one tries to investigate behavior of any substantial complexity, the processes of perception and analysis that one needs to use are no longer so straightforward. And the results one gets can then depend on these processes.

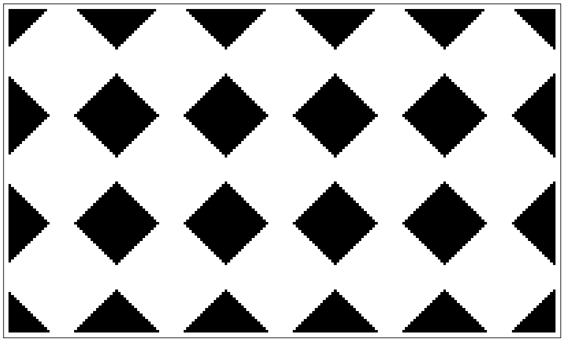
In the traditional sciences it has usually been assumed that any result that is not essentially independent of the processes of perception and analysis used to obtain it cannot be definite or objective enough to be of much scientific value. But the point is that if one explicitly studies processes of perception and analysis, then it becomes possible to make quite definite and objective statements even in such cases.

And indeed some of the most significant conclusions that I will reach at the end of this book are based precisely on comparing the processes that are involved in the production of certain forms of behavior with the processes involved in their perception and analysis.

What Perception and Analysis Do

In everyday life we are continually bombarded by huge amounts of data, in the form of images, sounds, and so on. To be able to make use of this data we must reduce it to more manageable proportions. And this is what perception and analysis attempt to do. Their role in effect is to take large volumes of raw data and extract from it summaries that we can use.

At the level of raw data the picture at the top of the facing page, for example, can be thought of as consisting of many thousands of individual black and white cells. But with our powers of visual perception and analysis we can immediately see that the picture can be summarized just by saying that it consists essentially of an array of repeated black diamond shapes.



An example of a picture that our powers of perception and analysis readily allow us to summarize quite succinctly in simple geometrical terms. At the lowest level, however, the picture consists of 24,000 black and white cells.

There are in general two ways in which data can be reduced by perception and analysis. First, those aspects of data that are not relevant for whatever purpose one has can simply be ignored. And second, one can avoid explicitly having to specify every element in the data by making use of regularities that one sees.

Thus, for example, in summarizing the picture above, we choose to ignore some details, and then to describe what remains in terms of its simple repetitive overall geometrical structure.

Whenever there are regularities in data, it effectively means that some of the data is redundant. For example, if a particular pattern is repeated, then one need not specify the form of this pattern more than once—for the original data can be reproduced just by repeating a copy of the pattern. And in general, the presence of regularities makes it possible to replace literal descriptions of data by shorter descriptions that are based on procedures for reproducing the data.

There are many forms of perception and analysis. Some happen quite automatically in our eyes, ears and brains—and these we usually call perception. Others require explicit conscious effort and mathematical or computational work—and these we usually call analysis. But the basic goal in all cases is the same: to reduce raw data to a useful summary form.

Such a summary is important whenever one wants to store or communicate data efficiently. It is also important if one wants to compare new data with old, or make meaningful extrapolations or predictions based on data. And in modern information technology the problems of data compression, feature detection, pattern recognition and system identification all in effect revolve around finding useful summaries of data.

In traditional science statistical analysis has been the most common way of trying to find summaries of data. And in general perception and analysis can be viewed as equivalent to finding models that reproduce whatever aspects of data one considers relevant.

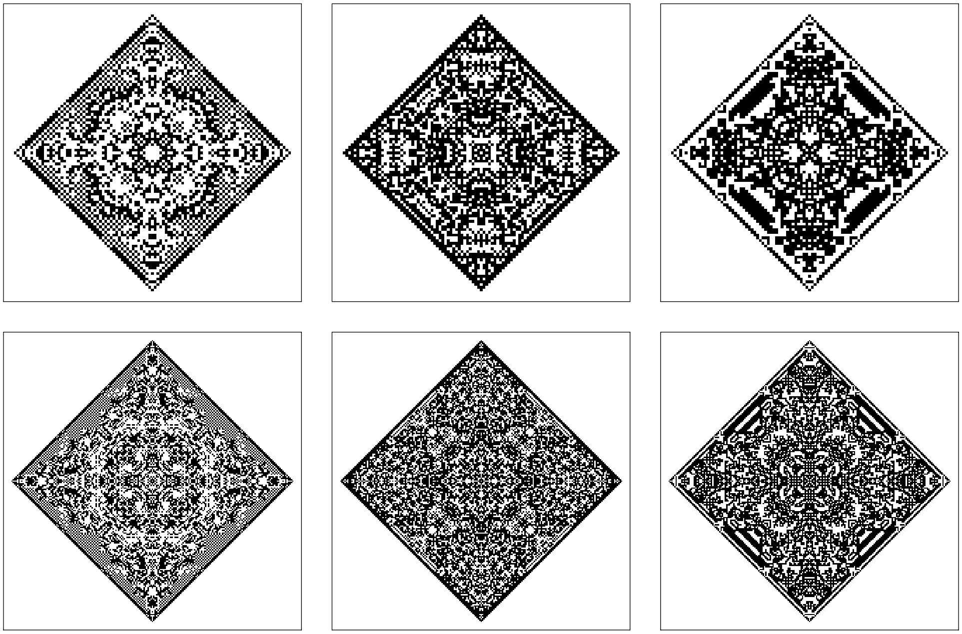
Perception and analysis correspond in many respects to the inverse of most of what we have studied in this book. For typically what we have done is to start from a simple computer program, and then seen what behavior this program produces. But in perception and analysis we start from behavior that we observe, then try to deduce what procedure or program will reproduce this data.

So how easy is it to do this? It turns out that for most of the kinds of rules used in traditional mathematics, it is in fact fairly easy. But for the more general rules that I discuss in this book it appears to often be extremely difficult. For even though the rules may be simple, the behavior they produce is often highly complex, and shows absolutely no obvious trace of its simple origins.

As one example, the pictures on the facing page were all generated by starting from a single black cell and then applying very simple two-dimensional cellular automaton rules. Yet if one looks just at these final pictures, there is no easy way to tell how they were made. Our standard methods of perception and analysis can certainly determine that the pictures are for example symmetrical. But none of these methods typically get even close to being able to recognize just how simple a procedure can in fact be used to produce the pictures.

One might think that our inability to find such a procedure could just be a consequence of limitations in the particular methods of perception and analysis that we, as humans, happen to have developed. And one might therefore suppose that an alien intelligence could exist which would be able to look at our pictures and immediately tell that they were produced by a very simple procedure.

But in fact I very much doubt that this will ever be the case. For I suspect that there are fundamental limitations on what perception and analysis can ever be expected to do. For there seem to be many kinds of



Patterns produced by taking a single black cell, then evolving for 50 and 100 steps according to outer totalistic cellular automaton rules 54, 222 and 374. Despite the simple description that can be given of this procedure, our standard methods of perception and analysis cannot readily deduce this description given just the final pictures shown here.

systems in which it is overwhelmingly easier to generate highly complex behavior than to recognize the origins of this behavior.

As I have discovered in this book, it is rather easy to generate complex behavior by starting from simple initial conditions and then following simple sets of rules. But the point is that if one starts from some particular piece of behavior there are in general no such simple rules that allow one to go backwards and find out how this behavior can be produced. Typically the problem is similar to trying to find solutions that will satisfy certain constraints. And as we have seen several times in this book, such problems can be extremely difficult.

So insofar as the actual processes of perception and analysis that end up being used are fairly simple, it is inevitable that there will be situations where one cannot recognize the origins of behavior that one sees—even when this behavior is in fact produced by very simple rules.