Theories in 3D visual perception

Zyg Pizlo

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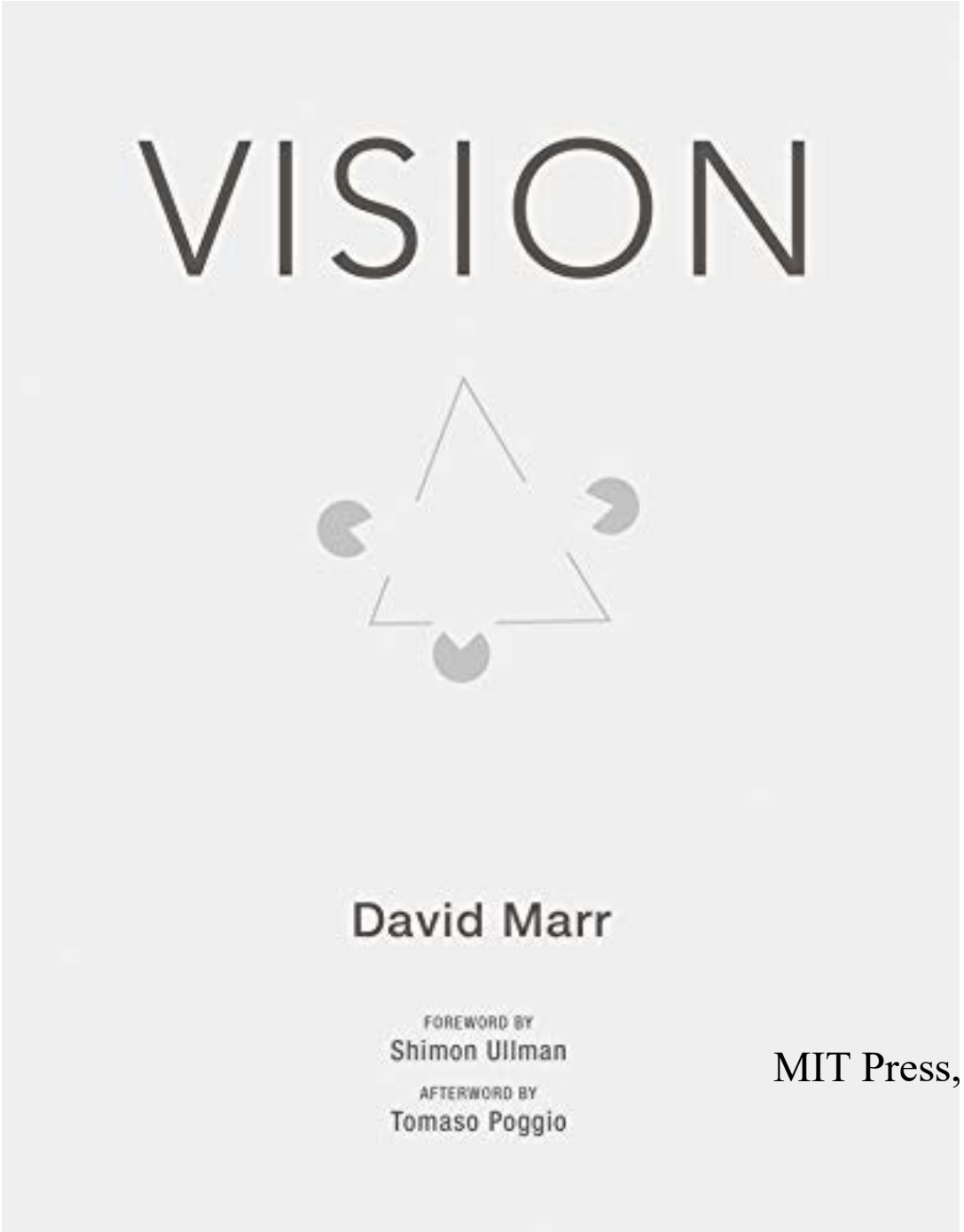
Marr's book on human vision (vision "bible") has no experimental data. Only theories…

How could Marr get away without collecting data from subjects…

Conventional wisdom has it that he did not have time to collect data – he died of cancer when he was only 35.



MIT Press, 1982

But there could be a deeper reason

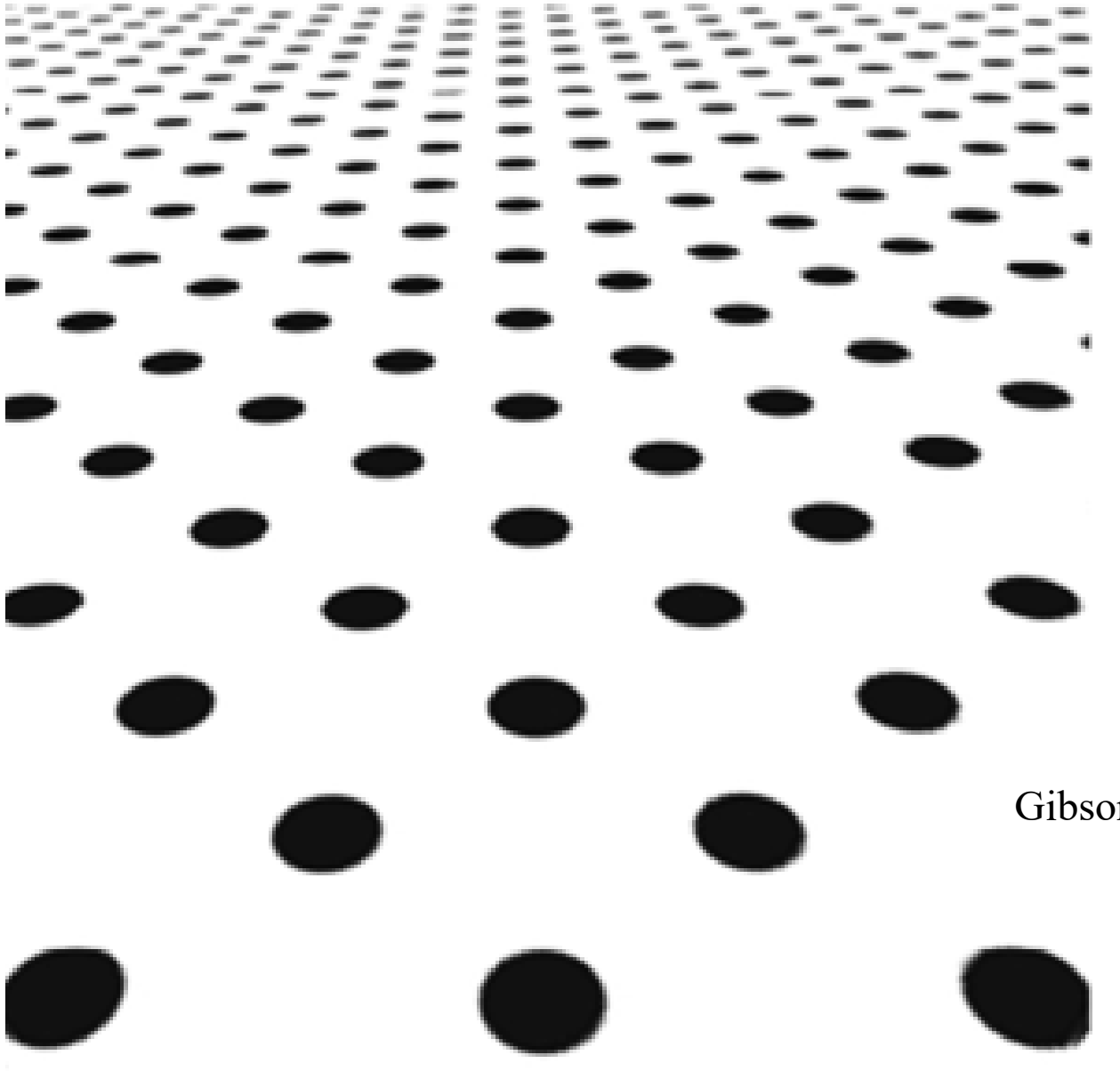
- Theories of 3D vision could be called “normative theories” because the theory is often formulated before data is collected.
- Normative theories work in 3D vision because there are not many different ways to produce a 3D interpretation from a single 2D image.
  - This is characteristic for an ill-posed inverse problem.
- Most cognitive inferences are probably like that.

I see a slanted surface. You see it, too.

How is it possible to produce a 3D interpretation from a single 2D image?

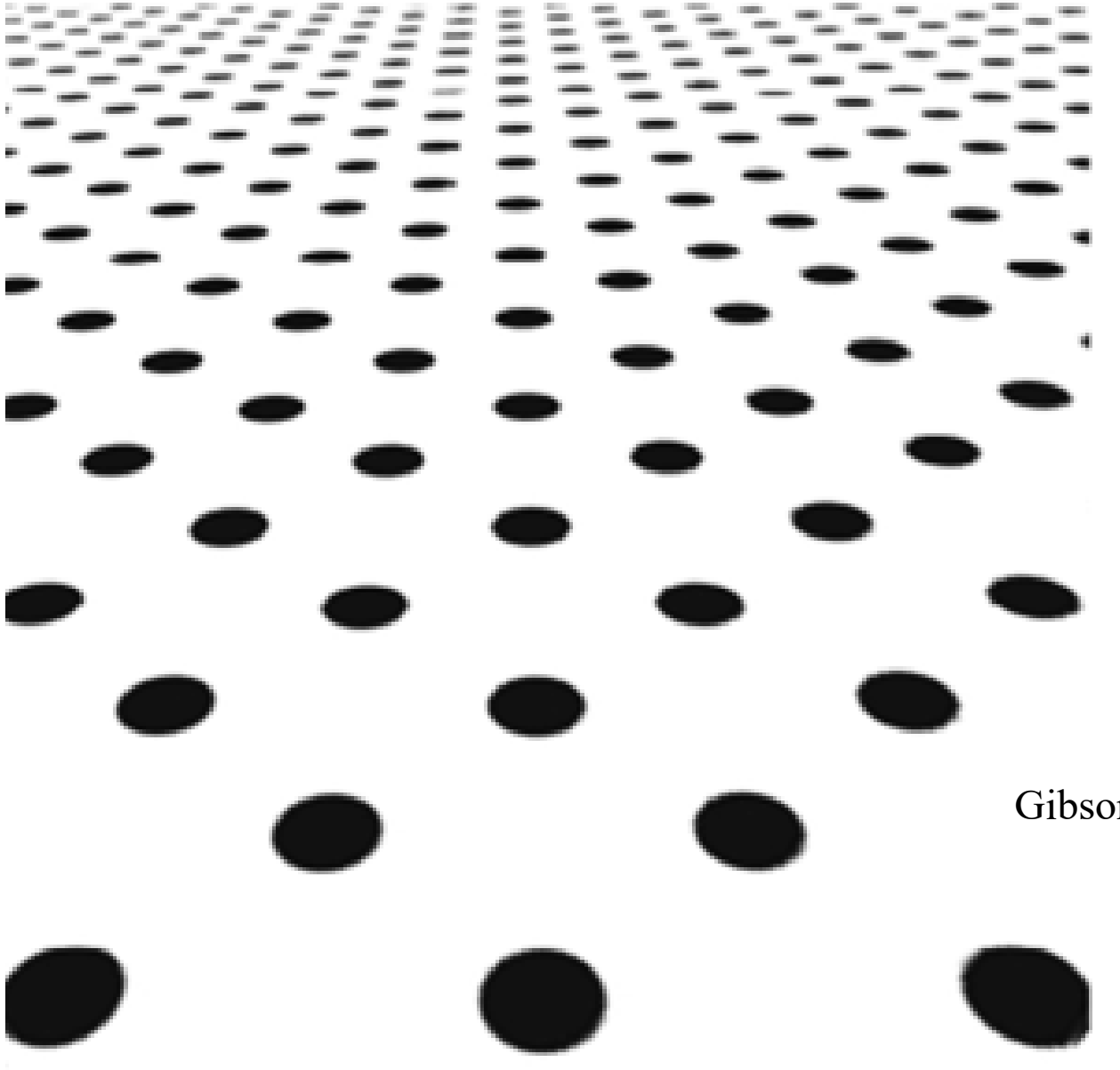
Before you start testing subjects, you must have a theory in order to design meaningful stimuli…

So, a theory can (must) exist before looking at empirical data.



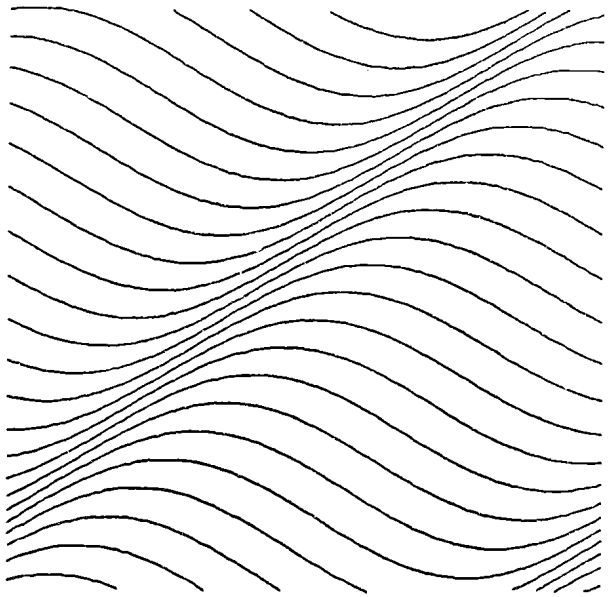
Gibson, 1950

The only way to start conceiving a theory for this observation is to conjecture that texture “out there” is assumed by the observer to be self-similar (symmetrical).



Gibson, 1950

Another similar example from 3D vision.



Stevens, 1979

Figure 5. Distance can be inferred from surface orientation: The undulating surface is suggested simply by phase-shifted sine waves (adopted from the artwork of Bridget Riley). In the absence of occlusion and other depth cues, the visual system probably interprets the local surface orientation, and from this derives a sense of depth. Observe that just as the local surface orientation would be ambiguous in this orthographic projection, the depth may be seen to reverse (especially along the diagonal strip where the contours are closely spaced).

3D surface from shading is analogous.

Everyone sees 7 bumps… The one in the center is larger than the other 6. But the height of all 7 is about the same.

The only way to produce a 3D percept here is to assume that the surface reflectance is uniform (isotropic, self-similar, symmetrical)

Kunsberg & Zucker, 2021

All examples of 3D vision known to me…

- are based on the concept of symmetry.
- Symmetry is a theoretical (mathematical) concept that exists before data is collected
  - Symmetry can be (is) known *a priori*
- Symmetry is essential (probably) because 3D vision is about making 3D inferences from 2D sensory data (difficult task of producing a unique one-to-many mapping).

Summary

- This is my 33,000. ft (10,000 m) view of theories in human 3D vision.
- In my work I do not have to justify why I am talking about theories.
- I never struggle with the following questions because it is easy to show how theories of 3D vision satisfy these criteria:
  - whether a theory has predictive power, or how it generalizes,
  - what does it mean when I say that a theory explains 3D vision,
  - whether the theory itself is explainable,
  - whether the theory can be falsified,
  - whether it is simple or only esthetically pleasing.
- Without theories, the discussion of 3D vision cannot even begin.
- Is the status of theories clearer in Behavioral Sciences than in Physics?