Bayesian confusions surrounding simplicity and likelihood in perceptual organization

Peter A. van der Helm *

Radboud University Nijmegen, Donders Institute for Brain, Cognition, and Behaviour, Montessorilaan 3, 6525 HR Nijmegen, The Netherlands

ABSTRACT

In the study of perceptual organization, the Occamian simplicity principle (which promotes efficiency) and the Helmholtzian likelihood principle (which promotes veridicality) have been claimed to be equivalent. Proposed models of these principles may well yield similar outcomes (especially in everyday situations), but as argued here, claims that the principles are equivalent confused subjective probabilities (which are used in Bayesian models of the Occamian simplicity principle) and objective probabilities (which are needed in Bayesian models of the Helmholtzian likelihood principle). Furthermore, Occamian counterparts of Bayesian priors and conditionals have led to another confusion, which seems to have been triggered by a dual role of regularity in perception. This confusion is discussed by contrasting complete and incomplete Occamian approaches to perceptual organization.

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1. Introduction

Bayes’ rule (Bayes, 1763/1958) is a powerful mathematical tool to model all kinds of things in terms of probabilities. In this article, I discuss two separate sources of confusion related to Bayes’ rule. One is the distinction between subjective and objective probabilities, and the other is the distinction between priors (or unconditionals) and conditionals (or likelihoods). I show that they have led to conflated lines of reasoning, and I show how unconfounded lines of reasoning look like. I discuss these issues in the context of research on perceptual organization, which is the process by which the visual system structures incoming proximal stimuli into interpretations in terms of wholes and parts, that is, into hypotheses about the organization of the distal scenes. The issue of subjective versus objective probabilities is introduced in Section 2 and discussed in Section 3, and the issue of priors versus conditionals is introduced in Section 4 and discussed in Section 5.

2. Subjective versus objective probabilities

Imagine one wants to model the outcome of randomly selecting a letter in a randomly selected English text. To this end, one needs the objective (i.e., the actual, or the right) frequencies of occurrence of letters in English texts. For instance, in English, the most frequently occurring letter is E so that, objectively, E has the highest probability of being selected. Such objective probabilities also underlie the Morse Code and Shannon’s (1948) classical information theory, for instance. Notice that these objective probabilities may not be suited to model the outcome of an experiment in which participants are asked to guess which letter is most likely to be selected. Participants invoke their own, subjective, ideas about frequencies of occurrence of letters and these may well disagree with the objective frequencies of occurrence. In other words, they use subjective probabilities, that is, probabilities which reflect a person’s beliefs regarding the occurrence of things — irrespective of whether these beliefs are veridical (i.e., truthful).

By the same token, in perception research, one might test people to assess the probabilities that they give certain interpretations for certain proximal stimuli. This way, one might model the outcome of the human perceptual organization process in terms of the probabilities people assign subjectively to interpretations. Notice that these subjective probabilities primarily reflect how likely humans are to give certain interpretations, that is, they do not necessarily reflect how likely these interpretations are to agree with the actual distal scenes. To assess the latter, one would also need the actual frequencies of occurrence of distal scenes in the world. This distinction is crucial, for instance regarding amodal completion, that is, regarding the question of how the visual system deals with everyday scenes yielding proximal stimuli that may be interpreted as objects partly occluding themselves or others. After all, for such proximal stimuli, the
visual system concludes to interpretations without knowing what the
distal scenes actually comprise.

In many domains, including perception research, a problem is that
the objective probabilities are unknown, if not unknowable. That is,
despite suggestions (e.g., Brunswik, 1956), it seems impossible to es-
tablish objectively the frequencies of occurrence of distal scenes in
the world. The point is that counting requires categorization and
that any categorization of distal scenes is a subjective one (Hoffman,
1996). This fundamental problem may be exemplified by way of
Bertrand’s paradox (Bertrand, 1889). In Fig. 1, this paradox is illus-
trated for the question of what the probability is that a randomly picked
outer-circle chord crosses the inner disk (see Fig. 1a). As illustrated
in Fig. 1b,c, the chords can be categorized (or parameterized) in dif-
derent ways — yielding different assessments of this probability.
In this case, as well as in perceptual organization, one may have compel-
ing arguments to choose a specific categorization, but the point is
that it remains a subjective categorization which, therefore, yields
subjective probabilities.

Hence, to be clear, by objective probabilities I mean probabilities
reflecting the actual or right frequencies of occurrence of things in
the world, and by subjective probabilities I mean any other choice
of probabilities. For instance, however compelling they may be, not
only probabilities based on intuition or on outcomes of perception ex-
periments but also artificially designed probabilities (see next sec-
tion) are subjective probabilities — simply because they do not
necessarily agree with objective probabilities in the world.

Bayesian models, for instance, usually start from subjective proba-
bilities. In some cases, this is simply because the very objective is to
model subjective judgements, but in other cases, it is because the re-
quired objective probabilities are unknown. As said, also in perceptu-
al organization, the objective probabilities are unknown. Yet, for the
sake of the argument, let us assume that they can be established. I
do not think this is possible, but as I discuss next, this assumption
does underlie one of the principles that has been proposed to guide
the perceptual organization process.

3. Perceptual organization

Perceptual organization is the process by which the visual system
structures incoming proximal stimuli into interpretations in terms of
wholes and parts. It is unclear exactly how it achieves this amazing
feat, but a long-standing debate concerns the question of whether
this process is guided by the Helmholtzian likelihood principle or by
the Occamian simplicity principle (for an extensive review, see van
der Helm, 2000).

The Helmholtzian likelihood principle, on the one hand, holds that,
for a proximal stimulus, the visual system chooses the interpretation
most likely to be true (von Helmholtz, 1909/1962). Feldman (2009),
for instance, characterized this principle as follows:

“Choose the interpretation most likely to be true. The rationale behind
this idea seems relatively self-evident, in that it is clearly desirable
(say, from an evolutionary point of view) for an organism to achieve
veridical percepts of the world.” (p. 875)

Hence, models of this principle assume that the visual system has
access to candidate interpretations as well as to their objective prob-
abilities in the world.

The Occamian simplicity principle, on the other hand, holds
that the visual system chooses the most simple interpretation,
that is, the one that due to regularities can be defined by the
least amount of information in terms of descriptive parameters.
Hochberg and McAlister (1953) introduced this principle as fol-
lowing (see also Attneave, 1954):

“The less the amount of information needed to define a given organi-
zation as compared to the other alternatives, the more likely that the
figure will be so perceived.” (p. 361)

To specify this further, they defined information loads (or com-
plexities) by:

“The number of different items we must be given, in order to specify
or reproduce a given pattern.” (p. 361)

Hence, models of this principle need a formal coding language to
describe and thereby categorize candidate interpretations, and a met-
tric to quantify their complexities.

Notice that the Helmholtzian likelihood principle is about uncon-
scious inference and holds that the visual system chooses the inter-
pretation which objectively is most likely to be true, that is, not that
it chooses the one which persons subjectively believe is most likely
to be true. It is true that such subjective beliefs result from uncon-
scious inference, but this is also what the Occamian simplicity prin-
ципле implies, and the central question is which principle drives the
unconscious inference leading to such subjective beliefs.

In this respect, the Helmholtzian likelihood principle is appealing
because it suggests that the visual system is highly veridical in
terms of the external world, and the Occamian simplicity principle
is appealing because it suggests that the visual system is highly
efficient in terms of internal resources. The debate between pro-
ponents of these two perceptual principles peaked in the 1980s
(see, e.g., Boselie & Leeuwenberg’s, 1986, reaction to Rock, 1983,
and to Pomerantz & Kubovy, 1986; Sutherland’s, 1988, reaction to
Leeuwenberg & Boselie, 1988; Leeuwenberg, van der Helm, &
van Lier’s, 1994, reaction to Biederman, 1987). Later, Chater
(1996) refueled the debate with an intriguing stance: he argued
that the whole debate was misguided because, as he claimed,
the two principles are formally equivalent. Though his proof of
this claim has been refuted (van der Helm, 2000), this claim did
find followers. Therefore, in the next subsections, I discuss this
claim from a different and less technical angle. That is, I argue
that it confused Bayesian approaches using subjective probabili-
ties and Bayesian approaches using objective probabilities. To set
the stage, I first give an overview of several issues and develop-
ments relevant to the simplicity versus likelihood debate in
perception.

3.1. Simplicity versus likelihood

Most people will agree that some degree of veridicality is a pre-
requisite of the human perceptual organization process, simply be-
cause it has to guide us through the world. This does not mean that
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