Preface

In his book *How to lie with statistics* the economics statistician Walter Krämer (1991) speculates that today in an average newspaper more statistics can be found than Goethe or Schiller experienced in their whole life. This is because today's consumers of media are overwhelmed by a deluge of data, numbers, facts, tables, curves, trends and tests. Furthermore, he claims that the word "percent" is probably the most frequent noun in the German language (Krämer, 1991, S. 51). Be that as it may, the new year's supplement of the German newspaper *Süddeutsche Zeitung* of 31th December 1998 publicized a striking finding of the opinion research center *Emnid*. In a telephone survey they asked people what the correct paraphrasing of "40 percent" is. The following three alternatives were given: one quarter, four out of ten, or, every fortieth. Only 54% of the respondents chose the correct alternative "four out of ten".

Statistical literacy is as indispensable for an educated citizen as are reading and writing because statistical innumeracy makes one vulnerable to confusion and exploitation through vague or meaningless statistical data provided by politicians, advertisment and media (see, e.g., Krämer, 1991; Dewdney, 1993). Unfortunately, what is commonly taught – both in schools and at universities – is usually limited to statistical recipes and calculations. Students learn to insert numbers into formulas of probability theory, but do not necessarily understand the meaning of what they are doing, as we demonstrate in Chapter 3. The great majority of contributions in the pertinent journals – like *teaching statistics,* the *journal of statistics education,* or the German *Stochastik in der Schule* – is written by statisticians and aims at improving students' ability to manipulate abstract symbols. Yet, to survive in the every-day life jungle of percentages and probabilities, the mere ability to manipulate abstract symbols is often of little help. Only statistical insight and the skills of statistical thinking guarantee proper decision making, good judgment under uncertainty, and reckoning with risk. However, concepts on how to improve statistical literacy of the ordinary person – or of experts in non-statistical domains such as judges or physicians – can be found only rarely in the statistical literature.

The present doctoral dissertation deals with the topic of *improving statistical insight*. Along the lines of Gigerenzer and Hoffrage (1995) and of Sedlmeier and

Köhlers (2001), *psychological tools* for analyzing people's difficulties and for improving their statistical thinking will be suggested. For instance, in the present dissertation, the format of the statistical information will be adjusted to human thinking – in chapters 1 and 2 the confusing concepts of percentage or probability could be totally abandoned.

The present dissertation chooses two cornerstones of inference statistics, namely *Bayes' rule* (Chapters 1 and 2) and *significance tests* (Chapter 3), which are both notorious sources of misunderstandings. Since both can be expressed in terms of conditional probabilities, the aim of the dissertation can be formulated in another way: It proposes how to teach and foster insight into problems that require a sound understanding of the concept of conditional probabilites. A key ingredient of a large part of this work are *natural frequencies*. As mentioned above, people have trouble understanding the expression "40 percent". Gigerenzer and Hoffrage (1995) explain this by the relative recent inception of percentages and probabilities in human culture. The expression "4 out of 10" instead is akin to human thinking, which is adapted to counting.

The dissertation is organized as follows: In the introduction we will give an overview of the history of science investigating people's ability to think statistically, beginning with the invention of probability theory up to the present. This introduces the problems connected with statistical thinking and motivates the research questions of the following chapters.

The common structure shared by all three chapters is: In each chapter, a relevant statistical problem is presented. After reviewing previous literature concerning the problem, crucial variables responsible for participants' difficulties regarding this problem will be analyzed. Then a psychological way of representing the problem that aims to overcome people's confusion will be developed. Finally, this pedagogical proposal is either empirically tested (Chapters 1 and 2), or a suggestion is made on how to implement it in statistics lectures (Chapter 3).

The present dissertation displays the main findings in a descriptive way. In Chapter 3 this approach is substantiated. Since several parts of the dissertation were collaborational work, in the following "I" mostly is replaced by "we". The formation of the collaborations will be elucidated in the section "Danksagung" (acknowledgment).