

# Critical Thinking

Understanding and Evaluating Dental Research

*Second Edition*

Donald Maxwell Brunette, PhD

Professor

Department of Oral Biological and Medical Sciences

Faculty of Dentistry

University of British Columbia

Vancouver, BC Canada

## Contributors

Kathryn Hornby, MLS, DMD

Medical Liaison Librarian

Woodward Biomedical Library

University of British Columbia

Vancouver, BC, Canada

Carol Oakley, DDS, MSc, PhD

Clinical Assistant Professor

Faculty of Dentistry

University of British Columbia

Vancouver, BC, Canada



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# Preface to the Second Edition

The need for a second edition of *Critical Thinking* was driven by three considerations: the changes taking place in dentistry and dental research, comments from readers, and finally my own determination that the rhetoric of science had to be given more emphasis in the book.

At the time the first edition was published, students and investigators typically searched the literature and index databases only indirectly via a professional librarian, who served as the mediator and search strategist. Today, researchers make searches from their own desktops. While the Internet has made research more convenient, the loss of professional advice has doubtless led to many inefficient and fruitless searches. This edition incorporates a chapter on searching the dental literature (see chapter 4), which is co-written by Dr Kathryn Hornby, a dentist with qualifications in library science and medical informatics.

Evidence-based dentistry has become a more important topic in the last 10 years, but one obstacle to its implementation is a lack of understanding by dental and other health professionals of the use of diagnostic measures in clinical decision making. The first edition included a chapter on this topic that some readers found to be somewhat abstract. Dr Carol Oakley, who has specialty qualifications in both periodontics and oral medicine, has rewritten this chapter (chapter 14) with an emphasis on practical examples.

I have found that some readers wanted more information on statistics in the book. To that end, I have expanded the sections on statistics to include more information on basic statistical principles (chapters 9–10 and throughout). Readers should know that this book is in no way comprehensive on this topic, but does

cover the most common concepts and tests used in dental research. References to more detailed statistical texts and material are also provided.

If you had asked me my profession 15 years ago, I would undoubtedly have answered “scientist” without qualification. Since then, I have come to realize that looking through a microscope, running a polyacrylamide gel, or analyzing data does not actually occupy a large portion of my working day. Instead, I write papers and referee the papers of others. I write grants and evaluate other people’s grants. As a department head I evaluated my faculty’s pleas for everything from merit increases in salary to early retirement. In turn I pleaded for all manner of things from my dean. As a professor I evaluate students’ essays and theses and coach my own students on how to write persuasive papers and theses. In sum, I spend a large part of my day either persuading or being persuaded. To put it another way, scientists today must play the role of rhetorician to be successful. In the same way, consumers of dental research must understand the principles of persuasion as applied to science in order to detect and separate the scientific signal from the rhetorical noise. Chapter 3 of this edition on rhetoric is informed not only by the classical approach to rhetoric, but also by more modern psychological studies as well as my own experiences as a reviewer of grants and publications and as a participant in panels that make decisions about funding.

Other chapters in the book have been updated and expanded with more recent information or more detailed consideration of certain topics, including argument maps (see chapter 21), abductive logic (see chapter 6), real-world research (see chapter 16), and

Simpson's paradox (see chapter 13). In all, the book has expanded some 32%, to make it both broader and more in depth than the previous edition.

Finally, readers are invited to visit the Quintessence website ([www.quintpub.com/CriticalThinking](http://www.quintpub.com/CriticalThinking)), where they can access software programs for performing simple statistical calculations as well as additional information on this subject. The site will be periodically updated, so readers should check back from time to time for more information.

I would like to express my appreciation to the many people involved in the realization of the second edition of this book.

I thank my wife Liz for her continuous support over the many years of my academic career that entailed considerable time away from home and more than a little shirking of domestic responsibilities. My son Max provided advice on aspects of law and logic, and my son Regan contributed some of the illustrations. That I place my family first on this list is no accident given their importance in my life, as well as the unfortunate fact that I egregiously forgot to thank them in the first edition—an omission, I might add, that was noticed, and one that I would not recommend to other authors.

As acknowledged in the preface to the first edition, my colleagues at the University of British Columbia have always been helpful in answering my questions concerning their disciplines. In this edition, I particularly would like to thank Dr Doug Waterfield for his

comments on all of the chapters and Dr Babak Chehroudi for his contributions to my thinking on many topics. It was a pleasure to work with Dr Kathryn Hornby and Dr Carol Oakley, who co-authored chapters 4 and 14, respectively; their contributions have made the book much stronger in their respective areas of expertise. Dr Ryan Woods of the HIV Network of Excellence commented on the presentation of statistical concepts and checked them for statistical orthodoxy and accuracy. A number of the members of my lab have been dragooned into various tasks and performed them graciously; in particular, I thank Leon Cheng and Mabel Cho for their help on the new illustrations for this edition and Dr Mandana Nematollahi for the drudgery euphemistically called "library work."

*Critical Thinking* is an unusual topic for a publisher such as Quintessence, which concentrates on books on clinical dentistry, and I am grateful to Tomoko Tsuchiya, who took the gamble of producing the first edition of this book; its success was a vindication of her judgment. The existence of this second edition is due in no small part to Senior Editor Lisa Bywaters, whose friendly advice and encouragement, as well as her occasional stern admonitions, were instrumental in keeping this book high on my list of priorities. Her skilful editing as well as that of Editor Bryn Goates and the work of Production Editor Patrick Penney have greatly improved the clarity and appearance of this edition.



# Preface to the First Edition

The intent of this book is to enable dentists, dental students, and graduate students, as well as allied oral health care professionals, to become sophisticated consumers of dental research. The book directly addresses the information management and critical thinking requirements of the American Dental Association Commission on Accreditation and the National Dental Examining Board of Canada, which require that students be able to locate, understand, and critically evaluate dental literature.

Research is a complex enterprise, but traditional courses ignore this complexity and heavily emphasize statistics. Although statistics is an important aspect of research, one has only to attend research sessions of the International Association of Dental Research, for example, and listen to the questions and comments to realize that statistics often play only a bit role in many discussions. Questions on method and interpretation are more common, and indeed the presentation of scientific data can be considered as a rhetorical exercise designed to convince readers of the truth of the author's interpretation.

Understanding this rhetoric requires an understanding of the elements of logic, including the logic of statistical inference, measurement, elements of statistics, types of errors, research strategies and designs, presentation of results, and lower forms of rhetorical life. The wide range of topics covered in this book more nearly represents, in my view, the intellectual skills and information needed to evaluate biological research.

This book evolved over a 16-year period from notes for a course on the evaluation of dental research given to undergraduate dental students and graduate students. The book has benefited from their comments

and reactions. The general approach to evaluating research given here is to encourage a healthy skepticism. Although such an attitude might appear to be unduly negative, it should be recalled that organized skepticism is generally considered to be the appropriate interaction between scientists. I noticed, however, that some students exposed to this material became hypercritical, and to counteract this tendency I added a section on forming balanced judgments. I also noticed that some of the students, while being skeptical about academic research, somehow accepted uncritically claims made by so-called alternative healthcare practitioners. At first this may seem surprising, but as noted by Peter Skrabenek (*Lancet* 1986;1:960) medical (and for that matter dental) education does not provide criteria for the demarcation of the absurd. To rectify this situation, I introduced a chapter on quacks, cranks, and abuses of logic into the book and course.

I am grateful to my clinical colleagues at the University of British Columbia, most particularly Drs Tim Gould, Michael MacEntee, Helen Scott, Babak Chehroudi, and Bob Priddy who commented on various topics, and Dr Ping Ma, formerly of the Department of Statistics at the University of British Columbia, now with Success Consulting, Surrey, BC, for checking the statistical calculations.

Developing and executing a novel course on evaluating dental research into the curriculum required the encouragement and assistance of my academic superiors, most particularly Tony Melcher, director of the MRC Group in Periodontal Physiology at the University of Toronto, and Leon Kraitz and Barry McBride, formerly heads of the Department of Oral Biology, and Dean George Beagrie at the University of British Columbia. Many secretaries and technical personnel

were involved in the production of various versions of the manuscript over the years, but I would particularly like to thank Clare Louie, Diane Price, Lesley Weston, and Kathy Wyder for their aid in editing the text and producing illustrations. While acknowledging all this assistance, I must also add that any errors that appear in the book are, of course, my responsibility. Finally I should note that one part of the way students are

evaluated in my course is that they must critique a paper found in the dental literature. The problem section is largely based on their submissions, and it is intended to provide concrete examples of how issues of logic, statistics, measurement, design, and argument are actually expressed in research publications. I would appreciate hearing from readers with additional examples.

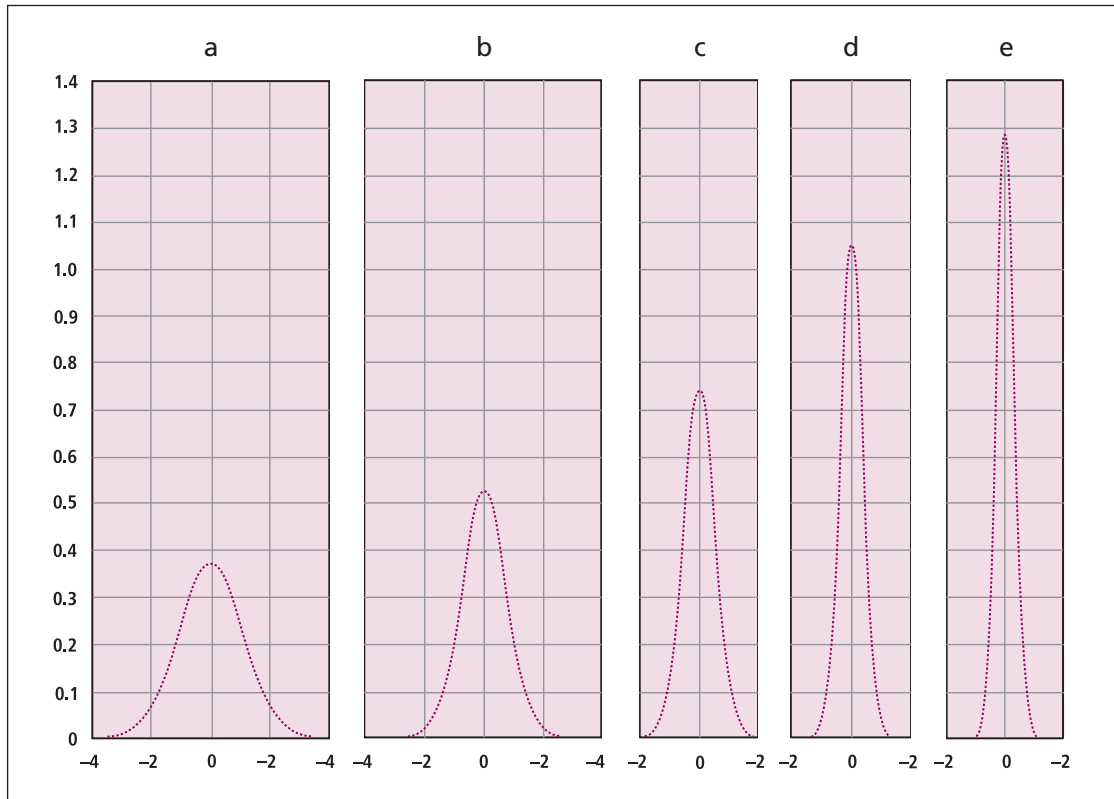


Fig 10-4 Effect of sample size on the expected distribution of means: (a) original distribution, (b) distribution of means of sample size of 2, (c) 4, (d) 8, (e) 12.

Assuming for the sake of illustration that the four samples have a mean of 147, the CI becomes:

$$\text{CI} = 147 \pm 1.96 \frac{5}{\sqrt{4}} \text{ ppm} = 147 \pm 4.9$$

Note that the CI has been halved by using a sample of 4.

### Sample from a population whose dispersion is not known “a priori”

Once again, suppose we want to measure sulfur levels in air expelled from the mouth, but we have offended Tonzetich because we refused to drink his homemade wine, Chateau Tonzetich. Therefore, we consult another biochemist; however, lacking Tonzetich’s experience, this biochemist does not have data to provide us with the SD of the measurement. But, because we (again) have four samples and hence four values, we can calculate an SD for our combined samples. The problem becomes how to use the SD calculated from the sample to arrive at the population’s SD. Fortu-

nately, this mathematical problem has been solved by Gosset, who published under the pseudonym *Student* so competitors would not know the sophisticated statistical control measures being used by his employer, Guinness Brewery. Gosset found that values could be calculated that could convert the samples’ SDs to the population’s SD  $\sigma$ . In brief, he derived these numbers, called the *Student distribution*, or *t distribution*, by sampling from a normal population. This exercise in probability theory yielded a distribution curve, the shape of which was found to depend on the size of the sample, or the number of *degrees of freedom* (*df*) of the sample. As the number in the sample increases, his curve approaches the normal curve. Based on Gosset’s work, CIs can be calculated as follows:

$$\text{CI} = \bar{X} \pm t \frac{s}{\sqrt{n}}$$

where  $\bar{X}$  = mean of sample (in this example,  $\bar{X} = 147$ )

$s$  = SD of sample

$n$  = number of observations

$t$  = a constant for a given number of *df* ( $n - 1$ ) and certainty



The actual value of  $t$  can be located in statistical tables (see appendix 3).

Thus, if the mean of the four samples was 147 and the SD was 10, the 95% CIs would be:

$$CI = 147 \pm t \times \frac{10}{\sqrt{4}} \text{ ppm}$$

From the table,  $t (df = 3, \sigma = .05) = 3.182$   
 $CI = 147 \pm 15.9$

## Estimation

Calculation of CIs is an example of *estimation*, the process whereby one calculates the value of an unknown quantity—here the level of sulfhydryl components—on the basis of a particular sample of data. There will always be some uncertainty associated with an estimate; that uncertainty is indicated by the CI—typically 95%. If, for example, one measured sulfhydryl levels in a subject’s mouth air with another four times (ie, four new samples) one would probably get a slightly different mean and a slightly different 95% CI. However, if the sampling process were repeated many times, we would find that the CIs calculated from our samples would cover the true population mean about 95% of the time.

From the perspective of dental clinicians, an important use of CIs arises during meta-analysis of the literature, in which the effects of a treatment found in different studies are compared. For example, Worthington<sup>3</sup> compared the change in attachment level in four studies of guided tissue regeneration. Figure 10-5 demonstrates that only one of the studies (Study C) included the value indicating no effect, and three of the studies had CIs that fell in the region favoring the control—ie, the untreated group. In meta-analysis, studies are often combined and weighted by such variables as number of subjects in the study to produce a combined CI.

An advantage of using CIs, as opposed to simple null hypothesis testing, is that one sees immediately the relative variation and range of possible effect sizes, rather than basing one’s decision on a single test. Moreover, as shown in the meta-analysis example, one can compare different studies directly or with regard to other methods of treatment. Another common use of CIs is to calculate the CI of the difference between two means, typically the difference between control and treated populations. If the CI includes

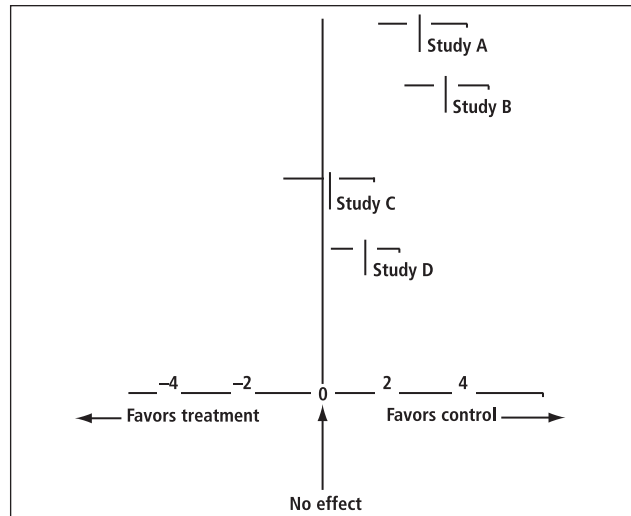


Fig 10-5 Example of a meta-analysis for the effect of a treatment for continuous outcome variable. Three studies (A, B, D) found the treatment to be less effective than the control. Study C found no effect.

zero, then the treatment has not been demonstrated to have a significant effect.

One might wish to use CIs to predict the results of hypothesis testing in comparing means directly. Intuitively, it would seem that if the 95% CIs for the estimated mean of two populations overlapped, then the means for the two populations (say, treated and control groups) would not differ significantly at the 5% level. However, CIs for two statistics can overlap by as much as 29% and yet the statistics can be significantly different.<sup>2</sup>

## Relationships Between the Normal, Poisson, and Binomial Distributions

The binomial distribution discussed earlier (and illustrated in Fig 9-5) lacks the familiar symmetrical bell-shaped appearance of a normal curve. However, if  $p$  (proportion of successes) or  $q = (1 - p) = 0.5$ , then the binomial distribution is symmetrical. Moreover, as  $n$ , the number of trials, increases to become at least greater than 20, and for any given probability  $P$  such that  $.2 < P < .8$ , it turns out that the binomial distribution can be approximated by the normal curve with:

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## Exercises in Critical Thinking

*It is difficult to overstate the value of practice. For a new skill to become automatic or for new knowledge to become long-lasting, sustained practice, beyond the point of mastery, is necessary.*

—Daniel T. Willingham  
from *Practice makes perfect perfect—  
But only if you practice beyond the point of  
perfection. Am Educator 2004; Spring:31.*

### Problems

The following excerpts from the dental literature are intended to illustrate some of the concepts introduced in the preceding chapters. To keep the section reasonably brief, the examples have been extracted from papers, and much detail has been omitted. In some instances, the authors discuss the weaknesses or strengths of the particular approach they employed in their article, which is not included here. The intent in presenting these examples is not to criticize or commend the articles in question, but rather to show how the arguments, strategies, and ideas discussed in this book appear in the dental (or popular) literature. To provide a wide range of examples in a reasonable amount of space, only select material was extracted from the papers. Often the problems contain a conclusion drawn from the abstract or summary of the paper and select material from other sections of the paper, such as Materials and Methods and Results, relevant to the conclusion. In approaching these problems, you should assume that the aspects of the conclusions that are not concerned with the information presented in the Materials and Methods and Results extracts are not problematic. For example, in Problem 1 assume that bone gain was actually achieved, even though it is not clear from the material that is presented how bone gain was measured, the time fluoride was applied, and so forth.

### Problem 1

Billar T, Yosepovitch Z, Gedalia I. Effects of topical fluoride in the healing rate of experimental calvarial defects in rats. *J Dent Res* 1977;56:53–56.

#### Summary:

“Bone gain was achieved after topical application of fluoride. Fluoride has a strong promoting effect on osteogenesis and accelerates the repair process of defects in membranous bone. No major histological differences are evident in the newly formed bone.”

#### Materials and Methods:

“In one half of the rats that underwent the procedure, a cotton wool swab soaked in 2% acidulated (0.1 M H<sub>3</sub>PO<sub>4</sub>) NaF solution was placed in the defect for 20 minutes. The area was then irrigated again with physiological saline solution. The scalp was then sutured. The remaining rats underwent the same local treatment with saline solution and served as controls.”

**Is this a positive or negative results paper? Is there any explanation, other than the effect of fluoride ions, that could explain the results?**

### Problem 2

Little JW, Wilson JC, Bickley HC, Bickley C. Effects of parathyroid extract on the rupture strength of intact skin of the rat. *J Dent Res* 1977;56:46–47.

#### Summary:

“Rats were injected with parathyroid extract (PTE) to search for possible effects on connective tissue of the skin. Rupture-strength analysis of skin samples showed a signifi-