sensitive" (a mouse is a graphics input device on PCs and modern workstations), so that clicking on an entry will cause the corresponding scatterplot to be displayed. Thus the convenient numerical summary that we have all come to know and love and suspect, is complemented by a graphical display that is available as needed. This is computing power working for us—it is what we should require software vendors to supply.

The second opportunity concerns so-called expert systems and how they attempt to embody statistical problem solving strategy. Our experience (Gale, 1986; Pregibon, 1986) with such systems is restricted to Polya's third step—carrying out the plan. (The first two steps involve the problem context to a sufficiently high degree that we do not expect rapid progress in bringing such systems to fruition.) Even this third step is challenging. Once we have the ability to encode a sequence of analysis steps into a software representation, we have a testing ground for strategies that use different sequences of steps or different techniques at each step. This suggests the following specific problem: Characterize the variability in the *process* of regression analysis. How might one go about solving the problem? Assuming that analytic solutions are intractable or not useful (overly simplified!), the only viable alternative is to appeal to computing technology. This includes both hardware to perform computations rapidly and software in which to represent the sequence of analysis steps and their associated techniques. Apart from our own attempt to bring computer power to bear on the problem (Lubinsky and Pregibon, 1988), we know of only one other serious attempt (Adams, 1990). Our journals and our textbooks are filled with an excessive amount of material on the *techniques* of data analysis. This energy should be applied to the *process* of data analysis. This poses an interesting challenge for the field, and computing technology provides a means to address it—who will heed the call?

Comment

Douglas A. Zahn

1. INTRODUCTION

This article is an important contribution to the literature on improving the quality of the services provided by the specialist statistician. The checklists and cases are useful to me; I will incorporate them in my practice and in the statistical consulting course my colleagues and I teach. I am confident that many others will also do this. I like the article's focus on avoiding trouble; it is reminiscent of old sayings such as "A stitch in time saves nine" or "An ounce of prevention is worth a pound of cure." In the language of the quality movement, the author is encouraging us to move upstream in our process as we seek to improve its quality.

I have two concerns about this article. I agree that avoiding trouble deserves more attention as a strategy for improving the quality of the statistician's services. However, this article addresses only the statistical aspects of avoiding trouble. It does not address how the relationship between the statistician and scientist relates to avoiding trouble. It also does not address how one might go about systematically improving the quality of one's services. In the words of one client from whom I have learned much, "Mere knowledge itself will not change behavior." What, in addition to checklists and good advice, will it take to change a statistician's behavior so as to produce improved services?

2. PITFALLS AND RELATIONSHIPS

I propose that the most important step for the statistician to take for avoiding trouble is to establish a working relationship with the scientist. A key part of developing this cooperative relationship is remembering that generally the statistician is involved in a project as a guest of the scientist. Other aspects of developing this relationship include aligning on goals with the scientist, being honest and not putting down, deriding or denigrating the scientist in any way, overtly or covertly, consciously or unconsciously.

Reflecting on this and rereading the article has led me to be concerned that the article is sending the wrong message to its audience, less experienced specialist statistician practitioners. To my ears, the article has the flavor of post-dinner conversations over drinks about how I saved science from the onslaught of those poor clients. I may be overly

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sensitive to this, since I have heard so many conversations like this at conferences when listening to statisticians discuss their clients. These conversations reveal an adversarial "us versus them" attitude about the relationship between statisticians and scientists. I will admit that this is an aspect of our profession's culture. However, I want to avoid passing it on to our less experienced colleagues; I am not aware of any authorities in quality improvement who advocate an adversarial relationship with one's customer.

I interpreted several passages in this article as reflecting either an adversarial or a condescending attitude toward scientists or the point of view that the problems are the scientist's fault. Following are several of these (identified by section and paragraph within section) and an interpretation of each that I might have, if I were the scientist and overheard the statistician saying this about our work together.

Prelude, paragraph 1. "Time is pressing (they want the results yesterday!)..." Interpretation: Those statisticians are always thinking, "Those foolish scientists! Always waiting until the last minute! If they had come in on time, I would not have had to cut those corners." Don't they realize that I also have other projects in my life and that I do not perfectly anticipate every deadline I confront? And furthermore, the statistician agreed to work on the project within this timeline.

Prelude, paragraph 3. "[T]he (ridiculous) default value..." Interpretation: What makes it ridiculous? No one in our shop ever mistook it for a real value like you did.

Example 1, paragraphs 1 and 2. Interpretation: I can't win: I feel ridiculed here for allegedly knowing what I want and for requesting only a few minutes of time to ask a simple question. When I come to see a statistician without a clear idea of what I want, then I get ridiculed for being unfocused and unprepared. The reason I ask for only a few minutes for a simple question is that I have found that to be the most effective strategy to get into a statistician's office.

Example 4d. "Only when the data had already been collected did the client reveal that...." Interpretation: You make it sound like I purposely withheld critical information from you. If it was so critical, why did you not get this aspect of the design clarified before doing it?

Example 5, last paragraph. "This late divulgence of crucial information caused some annoyance." Interpretation: With whom are you annoyed? It sounds again as if you think I have consciously withheld information from you. I did not. There were many aspects of the experiment. I left it to you to explore what you thought to be the essential aspects. Why are you annoyed at me for your failure to ask a question?

Example 6, last paragraph. "[T]he statistician must be careful not to let the analysis be constrained by the client's prejudices." Interpretation: I find it demeaning that you consider my hunches based on my years of experience as "prejudices." I think it is dangerous for you statisticians to think that you always have a better plan of action than we scientists do.

I emphasize that these interpretations are only my best guesses at how some scientists might react to these statements. However, they are based on numerous conversations I have had with scientists about situations such as these. I have sought to demonstrate that often when we say something that can be interpreted as demeaning, a demeaning comment is then returned to us. Many of these passages also involve a mistake being made and an ensuing conversation about who is to blame. I find conversations about fault and blame to be not useful when seeking to improve quality; a far more useful conversation addresses the question, "How did this mistake occur?"

3. AN IMPORTANT PITFALL: NOT BEING REHIRED

An important pitfall that has not been addressed is not being hired again by a scientist or not having a scientist return after a first session. This pitfall is important if one's job depends in any way on producing satisfied clients. On reflection, I propose that this pitfall occurs because the scientist does not think that another project or session with the statistician will be useful.

The source of this pitfall is often in initial stages of a project where the statistician assesses the wants and needs of the scientist, reconciles them, identifies resources and then determines what he or she is willing and able to do in the situation posed by the scientist. Problem formulation, which Chatfield discusses in Section 3.1, is part of this process. And much more is involved. As he notes, problem formulation is often sketchy at best. I agree. Numerous video tapes that I have seen of sessions involving statisticians ranging from novices to individuals with 30 years of experience demonstrate the difficulty in laying a solid foundation for the work to come. What I often notice is that the statistician discusses with the scientist what is to be done until a statistical problem appears. Then the statistician is off after it, without exploring whether work on this problem will address the wants and needs of the scientist.

Many difficulties between statisticians and scientists can be traced to the early parts of a consulting relationship. Hence, at FSU we spend a large part of our course Introduction to Statistical Consulting teaching students about them. We have students do several practice sessions to discover the difficulties in the early parts of sessions in order to become more proficient at getting sessions and projects started. In the hope of providing additional guidelines for less experienced specialist statistician practitioners and stimulating dialogue on this part of the consulting process, I will summarize some of this information here.

The difficulties with the initial parts of a consultation appear to stem in part from a lack of skills and awareness in the statistician and in part from attitudes of the statistician.

3.1 Components of the Start of a Consultation

The "wanted-and-needed conversation" in the early part of a consultation is a challenging combination of many components. The components include identifying: (1) what the scientist wants from this particular session; (2) the scientist's goals in several areas: the immediate question, the study as a whole, how the study relates to the scientist's discipline, professional, and personal; (3) what the scientist needs, that is, what steps are required to progress toward the goals; (4) the resources available in the areas of time, expertise, computing, money, etc.; (5) the statistician's initial assessment of what progress he/she thinks is possible toward the stated goals, given the resources available, and the statistician's initial assessment of whether he/she is willing professionally, morally, and ethically to undertake the tasks at hand; and (6) whether the costs and benefits are such that each party is willing to work with the other.

Clearly there are many components here. In our experience, this conversation is iterative: It is done initially and then as statistical work is done, new information is discovered which affects some aspect of wanted/needed/willing/able. The wanted-and-needed conversation is then revisited and a new working relationship is forged. Ignoring any one of the components in the wanted-and-needed conversation is dangerous. Doing so involves assuming that the other party has the same opinion of it as you do, which is dangerous at best.

3.2 Skills

Lack of skills contributes to statisticians' difficulties in early parts of sessions since this part of the session often demands that the statistician participate in a conversation for which he/she had had little or no training. We find it useful to model dialogue here. For example, here is a strategy we teach for dealing with scientists having a "five minute question:"

SCI: Hi! Do you have five minutes? I have a short question for you.

STAT: I do have five minutes now, but no more. If it looks to be longer than five minutes, I could see you for a regular session tomorrow afternoon. Is that OK?

SCI: Sure. But I do think it's only five minute.

STAT: Well, sometimes I do get short questions, but often additional information is required which requires more time to do a good job of answering your question. So, what is your question? (Dialogue on the question. At the four minute mark, if it is clear that the conversation cannot be completed in one more minute, STAT says:)

STAT: I have only one more minute now. I don't think I can do a good job answering your question in that time. What time tomorrow afternoon would be a good time for you for continuing this conversation?

3.3 Attitudes

Attitudes held by the statistician can also create difficulties in the initial stages of a project. Some statisticians appear to think that scientists should not arrive and say, "I have a 5 minute question," "Show me what formula to use," "I have an easy problem" or "We need this large study done quickly." The thought that scientists should not arrive in this condition often evolves into the thought that scientists who say these things are bad scientists and are difficult to work with. Not surprisingly, this often becomes a self-fulling prophecy.

A basic attitudinal problem is that many statisticians see scientists as the adversary and develop a competitive rather than cooperative relationship with them. Evidence of this attitude can be seen in how the statistician requests seeing the scientist's data.

If the statistician insists on seeing the data and tries to force the issue, he/she may win the battle and lose the war. Some statisticians appear to think they can force a scientist to do things; I think this is dangerous. Sabotage and poisoning the future of the relationship are potential consequences of attempting to force an issue. This does not mean that I oppose asking to see the data. All I am suggesting is to remember that this is a request being made by

the statistician who usually is a guest invited by the scientist. This implies to me that the statistician has the job of selling the idea to the scientist that showing the data to the statistician will be useful. When this sale is made, the scientist is enrolled in thinking this action will be useful and does it from this point of view rather than from the point of view that he/she was forced to do it. Most people I have talked with have vivid memories of how differently they do a task when they feel forced to do it rather than when they are enrolled in doing it.

4. SYSTEMATIC QUALITY IMPROVEMENT

Another important step to take to avoid trouble is to implement a process for systematically learning from one's past troubles. I have described such a process in Zahn (1988).

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I am grateful to John Fox, Duane Meeter, Gayle Muenchow and Andrea Zahn for extensive conversations on the Chatfield article which were most helpful to me as I prepared this discussion.

Rejoinder

Christopher Chatfield

I would like to thank all the discussants for their encouraging comments and for the additional guidelines, instructive examples and references. (I would add one more reference, namely Feynman's, 1988, illuminating account of the space shuttle catastrophe discussed in Example 8.) Taken as a whole, the discussion contributions provide a valuable commentary on the article and should be read in conjunction with it. I am very grateful to Jim Zidek for organizing this discussion.

Most of the comments require no reply from me and the absence of any response to a particular point implies no value judgment on that point.

The role of IDA deserves brief comment. Let me emphasize that its relative importance varies considerably from problem to problem, depending on the background information, etc., and I agree with Bailey that subsequent sophistications in the "statistical" analysis are often less important than the IDA phase, while also agreeing that one should generally not let the final analysis be completely dictated by the IDA. I also agree with Andrews that it is best to keep the analysis simple wherever possible.

I am pleased that Mallows and Pregibon agree that the *process* of data analysis needs more attention and welcome their additional references, particularly Polya (1957), which I nearly included myself. Andrews' comments on the scientific process are also relevant here.

Clayton and Nordheim provide wide-ranging insightful remarks on problem formulation, design and analysis, and I particularly concur with their comment that an analysis may be "optimal" in a different way to that usually assumed in textbooks.

Zahn has provided much helpful comment on consulting skills based on his wide experience therein. The only note of discord comes when he interprets some of my remarks as reflecting an "adversarial or condescending attitude towards scientists." Let me make it clear that I entirely agree with Clayton and Nordheim that "the active involvement of the investigator is essential in a successful statistical investigation," and with Zahn that "the most important step for the statistician to take for avoiding trouble is to establish a working relationship with the scientist." Either I have expressed myself poorly, or Zahn has detected undertones to my paper that were not meant to be there (although, like other statisticians, I would be less than honest if I pretend that I never get exasperated with a "client"). As regards the "time is pressing" comment, let me explain that in that particular case the pressure was not being applied by the people doing the work, but by upper management who had imposed unrealistic deadlines. As for the Prelude, paragraph 3, I still think that a default value of 999 million is ridiculous whether or not one spots it straight away. The default value was not selected by the person I was working with, and he thought that it was ridiculous too! However I do agree that the statistician is at least partly (mostly?) to blame when he fails to extract crucial information from the client, and that we must be careful not to make statements that "put down" the scientist (although I expect most of us will do it unconsciously from time to time).

Glick's entertaining remarks touch on many sensitive issues and will strike a chord with those of us who have to handle "difficult clients." Even so I