FEEDBACK Reader/Author Dialogue

Regrettably, the inevitable has occurred. A reader advises that errors and inaccuracies have escaped the scrupulous attention of the editorial board and have been translated in print. This set up the exchange that follows between Christopher J. Shelley, CMfg/TE, who shares his views on an article and suggests corrections, and the response from Dr. Vedaraman Sriraman, the article's author. Constructive reader input on this or any other topic offered in the Journal is encouraged. **JS**

Shelley writes:

I always look forward to receiving *The Journal of Technology Studies* because it keeps me current with the perspectives, ideas, and technological focus that industrial technology programs are passing on to students. This is especially important to me as an industrial technologist because, unlike many of my peers, I pursued a career in industry rather than education. Needless to say, I was quite excited to see Dr. Sriraman's article "Introducing the Taguchi System in a Laboratory Course" for quality engineering to students in the Winter/Spring 1997 issue of the Journal. I often make use of many of the tools utilized in the Taguchi model, especially in the design of factorial and fractional (or partial) factorial experiments, which seemed to be the focus of the article.

As I read through the article, however, I became concerned on two levels. First, I found that the author seemingly made no attempt to utilize the guidelines of experimental design and presentation that are fundamental to the Taguchi system. However, this deviation from the Taguchi model was not a major issue. What was of far greater concern was that I was unable to reach many of the same conclusions about the data as the author, regardless of the presentation method.

My first concern with data interpretation began with the how the issue of main factor interaction was presented. The point of any factorial experiment design is to overcome the flaws of traditional experiment design by changing more than one factor at a time to reach a true performance optimum for the experiment (Bakerjian & Cubberly, 1989). Essentially, the factorial experiment not only looks at how a single factor affects the outcome, but how the interaction of all the factors being studied affect the outcome (Abell, 1995). This critical issue was not explained or shown. Without understanding this point, the essence of how to properly interpret data from an experiment utilizing the Taguchi method with full factorial design is lost (Roy, 1990).

In a two-level factorial experiment, each factor is set at two levels—high and low—and the article expresses these levels as 1 and 2. I typically use positive and negative signs to show levels, but this is a matter of semantics. Table 1 shows a typical example of how the factors and interaction effects would be laid out for a two-level full factorial experiment (Roy, 1990). Table 1 also shows the AB factors interaction effect matrix that Sriraman does not present.

Careful observation of Sriraman's Figure 2 (Factor Effects on the Mean Response Value) shows the plotted bars representing the A and B factors to be reversed. However, because the bars showing each level are very close in length (within 2%), this oversight may not be significant in this case. The author makes an observation that when A and B are set to level 1(-), the greatest compression strength is achieved. This is confirmed by the numerical data from the chart in Table 1. However, I would recommend a great deal of caution with accepting this method of data interpretation. Typically in factorial experiments, the high mean factor value is subtracted from the low mean factor (i.e., Mean Response/Main Effect/Average Effect), and an evaluation is made from that (Roy, 1990). In the case presented, Factor A would be -16.2; Factor B, -16.6; and Factor AB, +2.4. What does this tell the investigator? It simply says that Factors A and B have large negative effects with B being the greatest and AB having a smaller but positive effect. In fact, we don't know at this point which, if any, of these effects are significant without further information. One would have to manipulate the data further to determine the signal-to-noise ratio and the analysis of variance (ANOVA: confidence limit, standard error, degrees of freedom, etc.) of the experiment, but this is beyond the scope of this discussion (Roy, 1990).

The second issue Sriraman examines is factor effects on the variance of the mean response. In this example, he repeats in Figure 3 (Factor Effects on the Variance of the Response Value) the same reversal of A and B factors observed in his Figure 2. At this point, Sriraman makes a number of statements (all of which are suspect due to the reversal of A and B plots). These statements boil down to all factors seeming to have significant effects and indicating that a different graph is necessary to find which factor(s) have the least effect on variance. I concur on this point. However, I take issue with the fact that this additional graph is referred to as an interaction plot. Variances do not interact with each other, factors do. I would, however, agree that a plot of the same style as the interaction effect plot could be used to find the smallest variation.

The A and B factors seem, once again, to be reversed when plotting the third graph, Figure 4 (AB Interaction). The X axis should be labeled A1(-) and A2(+), and each of the plotted A lines should be labeled as their B factor counterparts. Because of this error, the conclusion that the author makes " . . . when Factor A is

Table 1

Experimental Runs

Run	Factor A	Factor B	Interaction of AB	Output Mean ($x10^3$ psi)	Output Standard Deviation ($x10^3$ psi)
1	1(-)	1(-)	2(+)	110.6	8.677
2	2(+)	1(-)	1(-)	80.1	2.302
3	1(-)	2(+)	1(-)	79.3	5.495
4	2(+)	2(+)	2(+)	45.0	2.550

set at level 1(-) and Factor B is set at level 2(+) the least variation results" is incorrect. When one examines the data in the chart in Table 1 using Sriraman's recommended combination, it yields a 5.495 x 10^3 psi sample standard deviation. This is the second highest standard deviation in the chart! The smallest standard deviation in the chart is 2.302 x 10^3 psi with a factor pairing of A2(+) and B1(-). If one relabels Sriraman's AB interaction plot, as I suggest, it can be seen that the lowest point on the graph now supports the data in the chart.

The final divergence in data interpretation that I would like to discuss is the missing graph of the items that do interact, the factors. The resulting graph is shown in Figure 1.

This graph shows that the plots of the A and B factors are very close to parallel, but not quite. This can be interpreted to mean that the two factors do interact, but not significantly.

What conclusion should an individual draw based on the data from Sriraman's experiment? Given the initial performance requirements of good compression strength and small variability of the same, the combination of Factor A at level 2(+) and Factor B at level 1(-) will produce the optimum concrete mix for this scenario. However, as I have attempted to show, the author had a different interpretation of data that resulted in a different mix being selected.

If Sriraman's selection were utilized in industry, there likely would be serious repercussions. At the very least, the company using it would have great difficulty competing with a company using my selection. To the extreme, as a result of the amount of the variance in the author's mix selection, catastrophic failure of the concrete in whatever construction form it is used is possible.

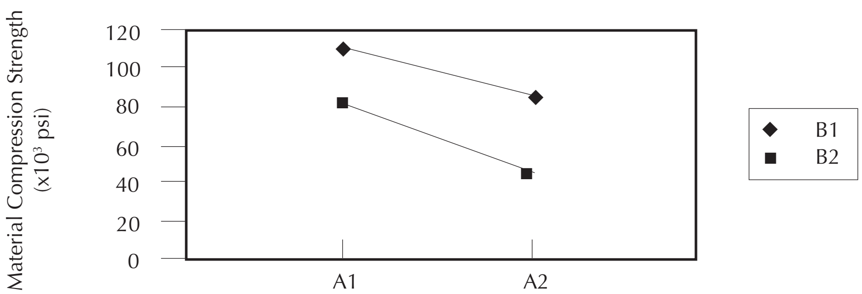

Figure 1. **A x B interaction (avg.).**

References

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Sriraman responds:

The article's intent was to introduce Taguchi methods and experimental designs in the manufacturing curriculum. Typically, an undergraduate course in quality control focuses on statistical process control and emphasizes control chart applications. The author's key point was to present Taguchi methods to an audience (students) that usually does not have detailed inferential statistics background. Also, the author factored into the article the viewpoint expressed by several Western statisticians (Box, Bisgaard, & Fung, 1988; Lochner & Matar, 1990; and Montgomery, 1996) that Taguchi's significant contribution has been that of making experimenters and statisticians aware of the value in using experimental designs to help reduce product and process variability. However, these statisticians have raised concerns with some of the mechanics of the procedures used in the analysis. Detailed experimental design procedures and ANOVA would certainly be appropriate for a second course in quality control. The following are some specific responses.

1. The author used graphical means for data representation because they convey the essence of the test results very well while also retaining a certain level of "user friendliness" for initial exposure to experimental designs.
2. In reference to interaction, the author has presented these effects in Figures 2, 3, and 4. Each of the figures are thoroughly discussed in the

body. A generalized discussion of factor interaction was excluded because the author made the assumption that technical educators were familiar with design of experiments and ANOVA theory.

3. The reader refers to his preference for designating factor levels that differ from those used by the author. However, several authors of well-respected books (e.g., Ealey, 1988; Lochner & Matar, 1990) use 1 and 2 to designate high and low levels.
4. The reader has made reference to details of interaction effects matrix construction. These details were originally part of the article but were excluded based on editorial suggestions (with which the author fully concurs) to "somehow integrate the experiment so that a neophyte could handle it."
5. In reference to the reader's comment on the need for further analysis of data in support of factor level settings for response maximization, the author used graphical interpretation because it is pedagogically the simplest means of introducing students to data interpretation. Many books on statistical inferencing use this approach for introduction purposes. In a semester-long course or a second course on the topic, further data manipulation using ANOVA would be a necessary addition.
6. The author did not use signal to noise ratios because these indices have been criticized by statisticians (Box, Bisgaard, & Fung, 1988; Lochner & Matar, 1990; and Pignatiello & Kamberg, 1985) who feel that it is better to use separate statistics to measure average response and response variability.
7. The reader lastly points out that the labels for A and B factors are reversed in the figures. Upon review, the author concurs and expresses his appreciation to the reader for correcting this oversight. The labels seem to have been reversed due to transcription errors when these figures were created on a graphics package. Consequently, in the original article in Figure 4 the Bs should have occupied the A positions and vice versa.

As a result of this change, the test data are to be interpreted as follows. Figures 2 and 3 lead to conclusions as suggested in the article. However, in Figure 4, the least variation can be clearly seen to occur for the following factor combination: A at Level 2 and B at Level 1. Consolidating the results, product optimization (maximization of compressive strength and minimization of variance) occurs if Factor A is set at Level 2, and Factor B at Level 1.

References

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Correction

We are pleased to recognize Mr. Onward Mandebvu as coauthor with Dr. John C. Dugger of a note in the Three Minute Philosopher section of the Journal's Winter/Spring 1997, Volume XXIII, Number 1 issue. At the time of writing the piece, Mandebvu was a doctoral candidate at Iowa State University. He is a member of Alpha Xi Chapter of Epsilon Pi Tau.