An Ounce of Preventative Research Design Is Worth a Ton of Statistical Analysis Cure[1]

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Abstract

This response addresses the data analysis issues raised by Wierenga and van Bruggen (1998) concerning Massetti (1996). Their analysis suggestions were performed and resulted in no significant differences between the treatment conditions. However, these analyses are misleading because of normality and variance problems present in Massetti's dataset. Specifically, not controlling for individual performance differences in ideational fluency ability during experimentation created the need for the complex, but appropriate, analysis approach used in Massetti. This response further suggests that ideational fluency be included as an independent factor in future research on individual creativity support systems.

Keywords: Ideational fluency, creativity support systems, idea generation, measures of creative performance

ISRL Categories: AA03, HA03, IB01, IB03

[1]Robert Zmud was the accepting senior editor for this paper.

Introduction

Given that new ideas are fundamental to developing and sustaining an organization's competitive advantage, research concerning technology's support of creativity can provide useful insights to systems professionals and managers (Kelly 1994; LaBarre 1994; Tapscott 1996). However, because of journal time and space limitations, research descriptions can occasionally contain information omissions that result in more confusion than enlightenment. When this confusion threatens to mask insights offered by research, further clarification becomes necessary. Fortunately, the skillful critique by Wierenga and van Bruggen (1998) of Massetti's work (1996) has not only identified procedural points needing further explanation, but has also drawn attention to a few key issues of research design that could improve the quality of creativity support system (CSS) research.

This response first considers design concerns relevant to Massetti and then addresses the analysis concerns introduced by Wierenga and van Bruggen.

Research Design and CSS

Although complimentary, Wierenga and van Bruggen were perhaps too accepting of the research design presented in Massetti. In actuality, had the design been more carefully developed, the results would have been clear and powerful without a complicated statistical analysis.

Several design oversights, however, created the necessity for a complex data analysis. First, a more interdisciplinary literature review would have been helpful. Although experimental practices from the group and decision support system literature were reviewed rather extensively, design aspects from the psychology literature were only cursorily considered. Within the psychology literature, *ideational fluency*—the ability of an individual to generate ideas (Torrance 1990)—has long been considered a significant, relevant independent variable impacting creative performance (see, for example, Frederiksen and Evans 1974; Hargreaves 1982; Hocevar 1979; Houtz and Speedie 1978; Milgram 1983; Milgram and Arad 1981; Sawyers et al. 1983). Traditionally, it has been accounted for within the psychology literature by recording the number of non-redundant ideas an individual generates before and after various treatment conditions. Within the group and decision support systems literature, however, ideational fluency has typically been operationalized as the number of non-redundant ideas generated *after* various treatment conditions. Consistent with this convention, Massetti's design included the quantity of ideas an individual generated as a dependent variable only. No initial consideration was given to the potential for individuals to vary consistently and significantly in their ability to generate ideas prior to experiencing treatment conditions.[2]

Second, pre- and post-creative ability measures were used in Massetti to identify and account for any subject differences not directly controlled for by design (i.e., factors such as cognitive style and ideational fluency). However, neither measure contained a direct account of ideational fluency. Subsequently, they were of limited use in exposing or controlling for this variable. Specifically, although the premeasure did ultimately emerge as a significant covariate in the revised data analysis, its contribution was not possible until ideational fluency had been accounted for statistically.

Mention of the Torrance Test for Creative Thinking (TTCT) by Wierenga and van Brugger was encouraging. Not only does the TTCT directly include ideational fluency as a determinant of creative behavior, but its scoring procedures also measure fluency before considering other creativity factors (e.g., originality, flexibility, or elaboration) (Torrance 1990). Given both the analytical power derivable from standardized pre- and post-measures, and the direct affect ideational fluency has been shown to have on creative performance, one would be wise to use the TTCT or a similar control measure when performing creativity research.[3]

Data Analysis Concerns

The multivariate model suggested by Wierenga and van Bruggen was considered during the initial stages of data analysis. However, because of variance and normality problems with the analysis and because no significant differences were noted (Wilks' lambda = .92, $p. > .51$ for the overall model, $F = 1.26$, $p > .30$ for the quantity variable and, $F = 1.55$, $p > .21$ for the creativity "composite" variable), a discussion of this model was not included in the final version of the published paper. In addition, several data transformations were attempted, including the one Wierenga and van Bruggen suggested, but because none corrected the problems, a discussion of these was also omitted from the final version of the paper.

To better understand the difficulties with the initial analysis, Figure 1 provides a frequency bar chart of the raw data for the number of ideas generated.

Rather than reflect the shape of a normal distribution, the frequency chart depicted two distributions in the data set: one with a mean of two and a relatively narrow spread and one with a mean of five and a wider spread. Although existing in an overlapping manner, there appeared to be two categories of individuals: those who generated relatively few ideas with little variability and those who generated more ideas with wider variability. As a result,

[2]This consideration did not occur until a conversation with a statistician/educational psychologist concerning the analysis problems with the data set.

[3]J. P. Guilford also has a test that directly accounts for ideational fluency (Davis 1992). It is also reasonable to develop project-specific tests, if one does not need to normalize the scores to the general population. Scoring approaches used by Milgram and Milgram (1976) may offer developmental insights.

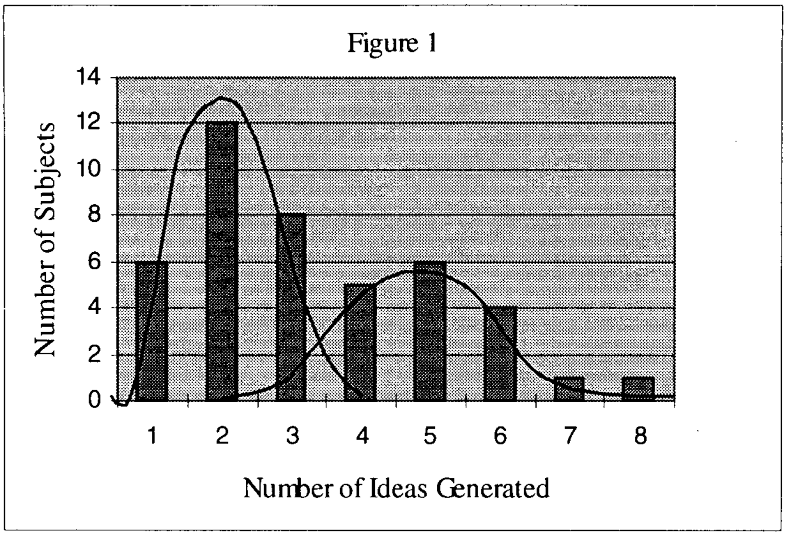

Figure 1. Graphical Representation of Ideational Fluency Data

Massetti concluded that, by chance,[4] high and low "fluents"[5] were present in the data set consistently enough to have wreaked havoc with the parametric assumptions and significance testing procedures. Hence, until ideational fluency was accounted for as a factor in the analysis, it is believed that any findings generated would have been misleading.

Given these conditions, the statistically appropriate course of action was to continue the analysis by accounting for ideational fluency ability differences. In specific, those subjects generating more than the mean[6] number of ideas were placed into the high fluency category, and those subjects generating the mean number or fewer were placed into the low fluency category. Table 1 provides the resulting means and standard deviations for the number of ideas generated by each of the categories.

As can be seen from Table 1, the overall fluency means and standard deviations reflect the distributions indicated in Figure 1. Unfortunately, Massetti only had one measure of the number of ideas subjects generated: the dependent quantity measure. For this reason, the quantity of ideas was converted from a dependent measure into an independent factor. Had additional measures of ideational fluency been present, other analysis approaches would have been possible.

Consequently, Wierenga and van Bruggen were correct in concluding that there are more effective ideational fluency measures available and that the statistical model in Massetti lost explanatory power as a result of the variable conversion. However, they were incorrect in concluding that an alternative data analysis would correct the problems and provide more powerful conclusions. The problem with the quantity measure in Massetti was fundamentally one of design, not analysis. Pre- and post-measures of the quantity of ideas produced by each subject should have been incorporated in the study's research design.

Moreover, if a non-parametric analysis had been applied in an attempt to avoid rather than explain the variance and normality problems present in the data, there would have been no

[4]Please note the importance of "by chance." Because ideational fluency was not controlled when assigning subjects to treatments, it is just as likely that fluency abilities could have appeared in the data set in such a fashion that the parametric assumptions would have been met. Furthermore, significant treatment differences might have been noted when, in actuality, performance variations were stemming from individual fluency abilities and not computer support options.

[5]Because there was only one measure for the number of ideas a subject generated, one cannot be certain these individuals were truly high and low "fluents." Given another problem task, they may or may not have performed similarly.

[6]Massetti used the mean value of 3.30 as a break point. However, the median value of 3.00 could have also been used and would have produced the same groupings.

Table 1. Numerical Repersentation of Ideational Fluency Data

Treatment/ Category	Pen and Paper	Harvard Graphics	Generative CSS	Exploratory CSS	Overall
High Fluency	4.00 (0.00)	5.00 (0.82)	6.20 (1.30)	5.00 (0.89)	5.24 (1.15)
Low Fluency	1.71 (0.76)	2.38 (0.52)	1.67 (0.82)	2.60 (0.55)	2.08 (0.74)

Note: Standard deviations appear in parentheses beneath each mean value.

estimation of the impact of CSS on creative performance. In specific, a non-parametric Kruskal-Wallis one-way analysis performed on both the quantity and creativity "composite" measures revealed no significant differences between the treatments for either variable (Chi-Square for quantity = 5.15, $p > .16$; and Chi-Square for creativity "composite" = 5.36, $p > 15$). Contrary to the suggestion of Wierenga and van Bruggen, the bimodal conditions present in the data set[7] could not have been more effectively addressed with non-parametric statistics.

Conclusions

Fundamentally, Wierenga and van Bruggen were correct in their conclusions. Both quantity and quality measures of creative performance should be included as dependent measures in creativity research. However, because the number of ideas an individual generates can be influenced by many factors including knowledge of the subject matter about which ideas are being generated (Sawyers et al. 1983), activation level (Voss 1977), and ideational fluency ability (Houtz and Speedie 1978), the contention here is that it is not enough to include the number of ideas an individual generates as a dependent measure only. Rather, two quantity measures are necessary: one before subjects undertake experimental procedures and one after. Otherwise, it becomes problematic to determine whether research results are stemming from treatment effects or from systematic bias similar to that found in Massetti.

[7]Please note that it is not being claimed, nor does this reponse mean to imply, that ideational fluency is bimodally distributed as a construct. It is most likely normally distributed (Torrance 1990). Clusters of high and low quantities were present in the data set because the impacts of ideational fluency were not controlled in the experimental design, not because that is the true shape of the construct's distribution.

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Brenda Massetti is an associate professor of information systems at St. John's University in New York. She is interested in investigating the effects of various applications of information technology including creativity support systems, group support systems, the Internet, and electronic data interchange on individuals and organizations. She has published in *Management Research News, MIS Quarterly, The Journal of Computer Information Systems,* and *The Journal of Information Systems Education.*