1983

The Impact of Color Graphic Report Formats on Decision Performance and Learning

Robert W. Zmud
University of North Carolina

Edward Blocher
University of North Carolina

Robert P. Moffle
North Carolina State University

The Impact of Color Graphic Report Formats on Decision Performance and Learning

Robert W. Zmud
Edward Blocher
School of Business Administration
University of North Carolina

Robert P. Moffie
Department of Economics and Business
North Carolina State University

ABSTRACT

One of the more common themes of the information systems literature involves the desirability of using graphics and color to enhance the usefulness of reports and displays. Very little empirical research, however, has been directed toward examining the real contribution of graphics and color to decision maker effectiveness; and, the findings of the few studies that have been undertaken are, at best, inconclusive. This paper reports on a laboratory experiment (using experienced internal auditors as subjects) that examines the contributions of color graphic outputs on decision performance and learning. Significant results were observed (controlling for individual differences) with color graphic reports proving advantageous with a simple, but not a complex, decision situation.

INTRODUCTION

Information system designers and researchers have both been deeply concerned with the impact of report and display formats on the usefulness of information systems outputs. Much has been written, for example, on the benefits of both graphics and color in enhancing the meaningfulness of management information. Such benefit is conjectured to occur for two major reasons (Benbasat and Taylor, 1982): by revealing relationships between information elements and by partitioned categories of information. Decision performance is thus believed to be directly facilitated through reducing the cognitive effort required of a decision maker in resolving a decision situation and by increasing the likelihood that reported "information" will be remembered for later use (Gremillion and Jenkins, 1981). Claims by proponents regarding the "managerial productivity" gains to be realized from graphics and color enhancements have, in general, not been modest (Ives, 1982).

Surprisingly little empirical research has been directed toward rigorously examining the claims of the graphics and color proponents. Furthermore, "... the research that has been done has produced equivocal findings. Neither graphics nor the use of color has been convincingly demonstrated to enhance managerial productivity" (Ives, 1982, p. 18). In his excellent review article on report/display enhancement strategies, Ives concluded (p. 38):

> The most urgent area of research that must be addressed is demonstration of decision maker productivity improvements attributable to the use of computer graphics. ... These should be designed to compare differences among individual decision makers, and more importantly, the characteristics of the task facing the decision maker.

This paper reports on a study intended to provide such evidence. Specifically, fifty-one experienced cost accountants participated in a laboratory experiment comparing the impact on decision performance and on learning of a color graphic report format against that of a tabular report format while controlling for task complexity and for selected individual differences.

DEVELOPMENT OF HYPOTHESES

Prior Evidence Regarding Color Graphic Enhancements

Previous research contrasting the contributions of tabular and graphical report formats on decision performance has resulted in quite inconsistent results with two studies reporting marginal support for graphical reports (Benbasat and Schroeder, 1977; Lucas, 1981), one reporting support for tabular reports (Lusk, 1979), and one reporting no difference (Lucas and Nielsen, 1980). These results, nevertheless, do suggest certain of the advantages of graphic and of tabular reports. Lusk, for example, discovered that subjects perceived the tabular reports as being less complex than the graphical reports, and Lucas (1981) disclosed that subjects with graphical reports developed a better understanding of the decision task. Lucas additionally reported stronger results (some favoring graphics, others favoring tables) when report format was interacted with cognitive style. He thus concluded that either format could be effectively used, depending on individual differences, in decision support.

Similar results have been realized from research examining the impact of color on learning (Chute, 1979; Lamberski, 1980). Essentially, the only definitive statement that can be made as a result of this literature is that it appears that a large number of intervening variables -- such as information content, learner aptitudes and context complexity -- strongly influence the effectiveness of color. While a study by Gremillion and Jenkins (1981) found that color learning aids outperformed black and white learning aids in an "information recall" task, no inferences could be made regarding the impact of color on decision performance.

A study by Ghani (1981) contrasted the impact on decision performance of color graphic reports and tabular reports in a complex decision task. While no significant results were reported, the tabular representations did result in higher decision performance. Post-experiment discussions with the subjects, however, revealed some interesting observations. While the subjects who preferred the color graphic representation emphasized the ease of perceiving relationships from the data, the subjects who preferred the tabular representations emphasized the ease of obtaining exact values from the data. The suggestion again arises that both report formats can be advantageous in particular decision situations.

Effects of Intervening Variables

An entertaining debate has arisen in the information systems literature regarding the relative influence of task characteristics and individual difference in explaining decision behaviors (Chervany and Dickson, 1977; Huber,

1983; McGhee, Shields, and Birnberg, 1978). While evidence does exist to suggest that individual differences do exert an influence on decision behaviors (Zmud, 1979; Keen and Bronsema, 1981), it seems clear that task characteristics most probably dominate. Humans, being both flexible and intelligent, seem very willing to adapt to those information processing behaviors most appropriate for a given task situation, given contextual pressures, even if their information processing preferences might suggest otherwise. Both categories of intervening variables, however, are considered here.

An important task characteristic in prior research on decision behavior is that of task complexity. A finding from behavioral decision theory very relevant to the present study is that decision makers appear to use simpler decision strategies, in order to reduce cognitive strain, as task complexity increases (Payne, 1976). Lucas and Neilsen (1980) apply a similar argument in explaining the lack of a significant effect for report format in their study contrasting the impact of graphical and tabular reports: the decision context was simply too complex to enable such an effect to emerge as a potent predictor variable.

Nonetheless, individual differences have been found to influence decision behaviors (Zmud, 1979). Two classes of variables consistently found associated with decision behaviors are decision maker demographic and cognitive attributes (Taylor and Dunnette, 1974). The demographic variables most commonly included in prior research studies are age and experience, with both generally found to be positively associated with decision performance. While cognitive styles (pervasive information processing habits and preferences) and cognitive skills (inherent or learned information processing abilities) have both been included in studies investigating information processing behavior, it is believed that cognitive skills are more appropriate when performances rather than preferences are being studied (Keen and Bronsema, 1981). One specific cognitive skill construct, field independence/dependence (Witkin, Oltman, Raskin, and Karp, 1971), has consistently discriminated among decision performances in related research (Benbasat and Dexter, 1979; Benbasat, Dexter, and Masulis, 1981; Benbasat and Dexter, 1982; Lusk, 1979). Field independents, in general, tend to outperform field dependents in structured decision tasks and tend to make more effective use of "transformed," i.e., aggregated values, graphical formats, etc., information.

Statement of Research Hypotheses

Given that prior research suggests that tabular reports are simpler than graphical reports, that graphical reports enable one to more readily perceive the relationships among a set of data items, and that humans tend to use simpler decision strategies as task complexity increases, the following interaction effect between task complexity and report format is hypothesized:

> H1--While color graphic reports will result in improved performance with less complex decision tasks, tabular reports will result in improved performance with more complex tasks.

Additionally, it is believed that the pattern recognitive advantages associated with graphical formats will produce a significant learning effect. Thus, the following hypothesis is stated regarding a main effect for report format on the development of effective decision rules to apply to a decision task.

H2--Color graphic reports will result in better early decision performance.

While individual differences are included in the experimental design foremost as control variables, it might be useful to hypothesize their influences upon decision performance. Based upon the findings of prior research, it is expected that demographic attributes will differ from cognitive skills regarding their influences on decision performance (Taylor and Dunnette, 1974). Two specific measures of decision performance, accuracy and confidence, are considered:

H3--Cognitive skills, but not demographic attributes, will be associated with decision accuracy.

H4--Demographic attributes, but not cognitive skills, will be associated with decision confidence.

Given the limited prior research examining possible interaction effects between these individual differences and either report format or task complexity, no formal research hypotheses are stated.

METHODOLOGY

The Decision Context

A common internal auditing task involves auditors assessing invoices submitted from contractors who have provided their firms with goods or services on contract. Because of limited resources, it is usually not feasible to examine all invoices; consequently, procedures to identify "high-risk" invoices are employed. This task can become fairly complex as a wide range of information elements could conceivably influence whether or not the auditor classifies a specific invoice as a "low" or "high" risk. This complexity has been reduced by a large utility company through the use of the following decision model: (1) only a limited number of cost categories are used, (2) each cost category is assigned a risk level, and (3) the products of cost category dollar amounts and risk levels are summed across cost categories to arrive at an invoice "risk score." Then, only those invoices with risk scores above a threshold value are selected for detailed auditing.

The Experimental Task

Subjects were provided with sample invoice information representing one of two risk score distributions: a low risk state and a high risk state. The means of these two distributions were separated by three standard deviations. Prior research has shown that this specification results in a discrimination task of reasonable difficulty (Blocher and Moffie, 1982). Each sample invoice contained the dollar amounts and risk levels for a set of cost categories. The subjects' task, then, was to identify an invoice as coming from the low or high risk population. Subjects were provided with the means and standard deviations of these two populations and were told that the sample invoices would appear as a 60/40 percent (low risk/high risk) mix.

The Experimental Variables

Dependent Variables

Decision performance was assessed by capturing a subject's identification of an invoice as being a low or high risk on a six point scale, anchored at either ends by the phrases "surely a low risk" and "surely a high risk." Decision accuracy was measured by determining whether an invoice was cor-

rectly identified, i.e., a low risk invoice being denoted with one of the three scale points on the "low risk" side of the rating scale and a high risk invoice being denoted with one of the three scale points on the "high risk" side of the rating scale. It was important for this decision task that subjects be "forced" to assign a sample invoice as coming from one of the two invoice populations. This rating scale also enabled an assessment of decision confidence with higher confidence associated with scale points toward the ends of the rating scale.

Each "trial" of the experiment consisted of seventy sample invoices being shown to the subjects. A subject's decision accuracy, then, was the total number of correctly identified invoices of the seventy that comprised the trial. A higher score represents more accuracy. A subject's decision confidence was calculated by summing up the confidence scores for all seventy sample invoices regardless of whether the invoice was correctly or incorrectly identified. Here, a higher score represents less confidence.

In order to assess subject learning the trial of seventy sample invoices was partitioned into thirds (sample invoices 2 thru 24, 25 thru 47, and 48 thru 70) and accuracy and confidence scores were calculated for each of these three learning periods. As the 23 sample invoices in each of these partitions were randomly selected from the population as a whole, task difficulty (i.e., the difference between an invoice's risk score and the "threshold risk score" across the three learning periods was not assured. To enable comparisons of decision performances between learning periods, "difficulty" scores were calculated for each set of 23 sample invoices and subject accuracy and confidence scores were appropriately adjusted.

Independent Variables

Two report formats were used to represent the sample invoices: a color graphic report in which cost category dollar amounts were represented in bar chart form against a black background and where four risk levels were represented by employing four different colors for the cost category "bars" (a color-coded legend associating each color with a numeric risk value was also imposed on the report); and, a tabular report in which the dollar amount and risk level for each cost category were portrayed in absolute numeric terms in white against a black background. Also, with the color graphic reports, "cool" colors such as blue were used to denote low risk levels while "hot" colors such as orange were used to denote high risk levels.

Task complexity was manipulated by using five cost categories on one set of reports, the low complexity treatment, and nine cost categories in a second set of reports, the high complexity treatment. This choice of five versus nine "cues" reflects the generally accepted boundary range of human information processing (Miller, 1956).

Covariates

Age and (internal auditing) experience were obtained from subject responses to a questionnaire handed out prior to the experiment. Field independence/dependence was assessed by administering the Group Embedded Figures Test (GEFT), again prior to the experiment. Information on the validity and reliability of this instrument is available (Witkin, Oltman, Rasking, and Karp, 1971). Finally, a second cognitive skill was assessed prior to the experiment via a quantitative ability test consisting of sixteen mathematical problems similar to those used in the GMAT. Prior administrations of this instrument had shown it to be a

reliable instrument for discriminating among subject quantitative ability (Blocher, Exposito, and Willingham, 1981). This second cognitive skill variable was included to provide a more "balanced" set of control variables: whereas field independent subjects might be expected to make more effective use of the color graphic report format, subjects with high quantitative skills should make more effective use of the tabular report format.

The Experimental Design

Not knowing beforehand the exact number of subjects who would actually participate in the experiment, a repeated measures design was employed. The fifty-one subjects who participated in the experiment were randomly split into two groups of 26 and 25 members. The first of these groups received only color graphic reports; the second, received only tabular reports. Each subject group sat through two complete trials of the experimental task. In both cases, the nine cue format followed the five cue format.

The Experimental Procedure

All fifty-one subjects were professional internal auditors and were registrants of a large regional auditing conference. None were color blind. Subjects were first given a one and one-half hour lecture, by one of the paper's authors, on the nature of risk analysis in auditing contractor cost reports. This lecture included a discussion of the risk analysis approach which is the basis of the study's experimental task. A thirty minute explanation of the experimental task was then given the subjects, again by one of the paper's authors. This was followed by a practice trial in which the subjects were exposed to ten sample invoices with feedback on the correct responses.

The experiment involved the subjects responding to the two successive trials, i.e., the five cue trial and then the nine cue trial, of seventy sample invoices, or 140 invoices in total. Each sample invoice was produced as a color slide, and each slide was projected for exactly fifteen seconds. This timing was selected through a pretest of the methodology.

In summary, the experiment involved a relatively structured task in which subjects were provided with an appropriate decision model but insufficient time to apply the model. Thus, rather than having to "discover" a decision rule, subjects had to develop an effective strategy for applying the decision rule.

RESULTS

The consistency of subject decision behaviors was analyzed with signal detection theory (Blocher and Moffie, 1982) to assess subject understanding of the experimental task. Trials for which unsuitably low consistency was observed were dropped from further analysis. This resulted in a final subject pool of 25 observations in both color graphic trials, 24 observations in the low complexity tabular trial, and 22 observations in the high complexity tabular trial. Table 1 shows subject scores on the covariates for both subject groupings, e.g., color graphic and tabular, and for all subjects taken together. This data indicates that (1) the assignment of subjects to these groupings generally appears to meet that of a random assignment and (2) the subjects are, in fact, experienced internal auditors. Correlations among the covariates, provided in Table 2, are as might be expected: while the two demographic and the two cognitive skill variables are associated, little association exists between these classes of individual differences.

Table 1. Descriptive Statistics on Covariates

	MEAN	STD. DEV.	F-STATISTIC
AGE:			
Color Graphic (n=25)	37.6	11.6	
Tabular (n=24)	33.5	8.6	
Difference			2.04
Overall	36.5	10.4	
EXPERIENCE:			
Color Graphic	10.2	7.5	
Tabular	9.7	9.9	
Difference			0.05
Overall	10.0	8.7	
GEFT:			
Color Graphic	11.4	5.0	
Tabular	11.0	5.7	
Difference			0.06
Overall	11.2	5.3	
QUANTITATIVE SKILLS:			
Color Graphic	7.4	2.1	
Tabular	9.2	4.2	
Difference			3.97*
Overall	8.3	3.4	

*P < 0.05

Table 2. Correlations Among the Covariates (n=49)

	EXPERIENCE	GEFT	QUANT. SKILLS
AGE	.78***	-.19	.02
EXPERIENCE		-.18	.13
GEFT			.42**

**P < .001

**P < .01

Table 3. Effect of Report Form and Task Complexity on Accuracy

(A) CELL MEANS (STD. DEV.)

	LOW COMPLEXITY	HIGH COMPLEXITY
COLOR GRAPHIC	52.12 (6.66)	43.12 (4.18)
TABULAR	49.81 (5.64)	47.23 (4.66)

(B) ANALYSIS OF VARIANCE (REPEATED MEASURES PROCEDURE)

EFFECT	df	F	SIGNIFICANCE
Report Form	(1,45)	0.005	.946
Task Complexity	(1,45)	50.91	.001
Interaction	(1,45)	15.09	.001

Table 4. Effect of Report Form and Task Complexity on Confidence

(A) CELL MEANS (STD. DEV):

	LOW COMPLEXITY	HIGH COMPLEXITY
COLOR GRAPHIC	146.41 (23.88)	157.14 (20.76)
TABULAR	149.36 (16.85)	153.88 (36.31)

(B) ANALYSIS OF VARIANCE (REPEATED MEASURES PROCEDURE):

EFFECT	df	F	SIGNIFICANCE
Report Form	(1,45)	.001	.979
Task Complexity	(1,45)	7.27	.01
Interaction	(1,45)	1.26	.267

The SPSS (Hull and Nie, 1981) analysis of variance procedure for a repeated measures design was used to assess the study's first hypothesis regarding an interaction effect between report format and task complexity on decision performance. Tables 3 and 4 give these results for decision accuracy and decision confidence, respectively. A strong interaction effect was present with decision accuracy: the color graphic report had the highest accuracy for low task complexity but the lowest accuracy for high task complexity. While a statistically significant interaction was not observed with decision confidence, it should be noted that the color graphic trials resulted in both the highest (low task complexity) and lowest (high task complexity) confidence measures.

These results provide fairly strong support for Hypothesis 1. With low task complexity, subjects seemed to be able to very effectively exploit the color graphic report format. While one can only surmise why this occurs, one probable explanation may be that relationships among decision cues were identified and then utilized in decision rules. With high task complexity, subjects with tabular reports performed better. While one can again only surmise explanations, a possible reason is that simpler decision rules focusing on a few decision cues were applied. Such explanations are consistent with prior research findings and with the appealing notion that humans, in their decision behaviors, strive to reduce cognitive strain.

The repeated measures design prohibited any effort to examine the interaction effects between task complexity and the covariates. It was possible, however, to employ the repeated measures analysis of variance procedure to assess the existence of any signifi-

cant interaction effects between each of the covariates and report format. Only two significant effects were found: an interaction between report format and quantitative skill for decision accuracy ($p < 0.01$), and an interaction between report format and experience for decision confidence ($p < 0.05$). Essentially, subjects with high quantitative skills performed better with tabular reports, and more experienced subjects exhibited higher confidence with color graphic reports. This provides moderate support that some concern for individual differences should exist when selecting report formats for decision support.

The influence of report form and task complexity on decision learning was assessed through correlational analysis. Table 5 presents the associations between the adjusted performance measures, report format (represented here as a binary variable with "1" representing color graphic reports), and the covariates for the low complexity trials. Table 6 reports the same results for the high complexity trials along with subject performance scores on the low complexity trial (included to control for subject task learning during the first trial).

While the results appear to suggest the presence of some learning effect, the implications are not entirely consistent with Hypothesis 2. Decision accuracy will be discussed first. With low task complexity, tabular reports appeared to result in better performance early in the trial. As the

Table 5. Correlational Analysis Regarding Learning Effects for the Low Complexity Trial (n=49)

	ACCURACY (ADJUSTED)			CONFIDENCE (ADJUSTED)		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Form	-.17	.37**	.30*	-.52***	-.02	.35*
Age	-.15	-.04	-.13	.21	.05	-.04
Exper.	-.24	.00	.06	.11	-.05	-.02
GEFT	.11	.37**	.27	.13	.06	.03
Quant.	-.16	.36**	.17	.06	-.07	.10

***P < .001

**P < .01

*P < .05

Table 6. Correlational Analysis Regarding Learning Effects for the High Complexity Task (n=47)

	ACCURACY (ADJUSTED)			CONFIDENCE (ADJUSTED)		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Form	.41**	-.50***	-.60***	-.23	.38**	.19
Age	-.28	.10	.26	.37*	.16	.25
Exper.	-.13	.12	.23	.42**	.32*	.26
GEFT	.07	-.09	.03	.03	.05	.07
Quant.	.17	-.24	-.07	.12	.32*	.23
Accur. (Trial 1)	.42**	-.30	-.10			
Conf. (Trial 1)				.54***	.53***	.67***

***P < .001

**P < .01

*P < .05

trial progressed, however, subjects with color graphic reports outperformed those with the tabular reports. Precisely the opposite occurred with high task complexity. While these findings are intriguing, we are unable to suggest why they occurred. This, however, is surely an important question for further research.

The results regarding decision confidence, however, do appear supportive of Hypothesis 2: subjects with color graphic reports were more confident early in a trial for both low and high task complexity. Interestingly, as the trials concluded (for both levels of task complexity) subjects with tabular reports tended to express more decision confidence.

In summary, some learning phenomenon does seem to exist regarding report format and the subjects' capability to develop effective decision rules. The nature of this phenomenon, however,

was not disclosed through this experiment.

The results reported in Tables 5 and 6 are consistent with Hypothese 3 and 4: subject demographic attributes tend to be associated more strongly with confidence than with accuracy, and subject cognitive skills tend to be associated more strongly with accuracy than with confidence. An interesting difference in the effects of these two classes of variables does arise. While the cognitive skill variables appeared to influence decision accuracy only under low task complexity, the demographic variables had their significant influence only under high task complexity. This moderating influence of task complexity may explain why very inconsistent and inconclusive results have, in general, been observed in research examining relations between individual differences and decision behaviors. Finally, while a subject's accuracy during trial 1 had little effect on decision accuracy in trial 2, a subject's confidence during trial 1 had a significant impact on decision confidence in trial 2.

Taken together, these findings strongly support the existence of an interaction effect between report format and task complexity, suggest that some (still unknown) learning phenomenon may exist regarding report formats, task complexity, and decision behavior, indicate that while individual differences are associated with decision behaviors (and to some extent interact with report format) they tend to be dominated by other factors, and are consistent with prior research indicating that subject demographic attributes are related to decision confidence while subject cognitive attributes are related to decision accurcy (as well as suggest that task complexity might be an important mediating variable with these relationships).

DISCUSSION AND CONCLUSION

The existing literature on the effects of color graphics has been, at best, inconsistent. The reasoning that lay behind the study's first research hypothesis, which was strongly supported, explains many of these inconsistencies. Color graphic reports can positively influence decision performance but only when the decision context is simple enough for relative complex decision strategies, i.e., those involving relationships among a number of decision variables, to be applied. As task complexity increases and subject decision strategies are simplified, less complex report formats, such as tables, seem to result in better decision performance.

Task complexity, thus, becomes a driving force in identifying appropriate report formats for decision support. An intriguing aspect of this notion involves a subject's traversal of a problem space in resolving a decision situation: subproblems, as they will vary in their degree of task complexity, should be approached with quite different report formats. This, however, will require a far greater understanding of decision strategy selection than currently exists in order that particular report formats could be automatically provided during decision support activities.

It should also be reiterated that the decision task employed in this experiment did not require the subjects to discover a decision rule. The subjects were provided with an effective decision model but were not given sufficient resources to apply the rule precisely as described. The decision task, thus, involved subjects arriving at an effective strategy for applying the decision model (or some variant of the model). These results clearly should not be generalized beyond such a decision task. It is suggested that further research efforts should both

validate the findings of the present study for similar as well as for different decision tasks.

While no clear findings emerged, the study's results do indicate that some learning phenomenon was present regarding the subjects' decision behaviors: reversals were observed in the directionality of the association between report format and decision performance as the decision trials progressed. Interestingly, a contrasting sign reversal was observed for decision accuracy across the two task complexity levels but not for decision confidence. It seems that both report formats can facilitate early learning depending on task complexity. While the color graphic format produced higher decision confidence early with both complexity levels, higher decision confidence in the latter periods of both trials was associated with the tabular format. This finding also attests to the advantages of manipulating report formats during decision support activities. It is not clear exactly why the tabular formats produced higher confidence later in the decision trials. Further investigation of this issue in particular is advocated as it might be very advantageous to instill increased confidence within a decision maker at the conclusion of decision support activities.

One of the major limitations of this study was the use of a repeated measures design. Not only did this design prohibit a full analysis of the covariate effects, but it also induced a "carry-over" effect in subject decision behaviors across the two complexity level trials. Thus, it is impossible to accurately interpret any learning phenomena associated with the high complexity trial. Future research should overcome this limitation. Additionally, if learning effects are to be accurately assessed, it becomes important to debrief subjects throughout a decision trial. Such information, as was gained by Ghani (1981) at the conclusion of his experiment, is invaluable in uncovering subject decision strategies and in validating statistical analyses.

While individual differences did exert some influence on decision behaviors, these effects were dominated by report format effects across both complexity conditions. This should not be taken to imply that individual differences are unimportant. They can influence decision behaviors (although the extent of these effects depends on the task context) and, consequently, should be considered in the design of decision support systems.

In conclusion, this experiment has contributed to an improved understanding of the effects of color graphics on decision performance. Much remains to be learned, however, and further research extending that of the present study is vigorously encouraged.

REFERENCES

Benbasat, I. and Dexter, A.S. "Value and Events Approaches to Accounting: An Experimental Evaluation," The Accounting Review, Volume 54, Number 4, October 1979, pp. 735-749.

Benbasat, I. and Dexter, A.S. "Individual Differences in the Use of Decision Support Aids," Journal of Accounting Research, Volume 20, Number 1, Spring 1982, pp. 1-11.

Benbasat, I. and Schroeder, R.G. "An Experimental Investigation of Some MIS Design Variables, MIS Quarterly, Volume 1, Number 1, March 1977, pp. 37-49.

Benbasat, I. and Taylor, R.N. "Behavioral Aspects of Information Processing for the Design of Management Information Systems," IEEE Transactions on Systems, Men, and Cybernetics, Volume SMC-12, Number 4, July/August 1982, pp. 439-450.

Benbasat, I., Dexter, A.S., and Masulis, P.S. "An Experimental Study of the Human/Computer Interface," Communications of the ACM, Volume 24, Number 11, November 1981, pp. 752-762.

Blocher, E., Exposito, R.S., and Willingham, J.J. "A Study of Auditor Judgements Concerning the Nature and Extent of Analytical Review in Auditing Payroll," unpublished paper, University of North Carolina, Chapel Hill, North Carolina, October 1981.

Blocher, E. and Moffie, R.P. "A Signal Detection Model for Analyzing Accounting and Auditing Judgements," unpublished paper, University of North Carolina, Chapel Hill, North Carolina, April 1982.

Chervany, N.L. and Dickson, G.W. "On the Validity of the Analytic-Heuristic Instrument Utilized in 'The Minnesota Experiments': A Reply," Management Science, Volume 24, Number 10, June 1978, pp. 1091-1092.

Chute, A.G. "Analysis of the Instructional Functions of Color and Monochrome Cuing in Media Presentations." Educational Communications and Technology Journal, Volume 27, Number 4, Winter 1979, pp. 251-263.

Ghani, J.A. "The Effects of Information Representation and Modification on Decision Performance," unpublished Ph.D. dissertation, University of Pennsylvania, 1981.

Gremillion, L.L. and Jenkins, A.M. "The Effects of Color Enhanced Information Presentations," Proceedings, Conference on Information Systems, Boston, Massachusetts, December 1981.

Huber, G. "Cognitive Styles as a Basis for the Design of DSS and MIS: Much Ado About Nothing?," Management Science, Volume 29, Number 5, May 1983, pp. 567-579.

Hull, C.H. and Nie, N.H. SPSS Update 7-9, McGraw-Hill, New York, New York, 1981.

Ives, B. "Graphical User Interfaces for Business Information Systems," MIS Quarterly, Special Issue, December 1982, pp. 15-47.

Keen, P.G.W. and Bronsema, G.S. "Cognitive Style Research: A Perspective for Integration," Proceedings, Conference on Information Systems, Boston, Massachusetts, December 1981, pp. 21-52.

Lamberski, R.J. "A Comparison and Critical Review of the Methodology and Findings in Color Investigations," paper presented at the Annual Convention of the Association for Educational Communications and Technology, 1980.

Lucas, H.C., Jr. "An Experimental Investigation of the Use of Computer-Based Graphics in Decision Making," Management Science, Volume 27, Number 7, July 1981, pp. 757-768.

Lucas, H.C., Jr. and Nielsen, N.R. "The Impact of the Mode of Information Presentation on Learning and Performance," Management Science, Volume 26, Number 10, October 1980, pp. 982-993.

Lusk, E.J. "A Test of Differential Performance Peaking for a Disembedding Task," Journal of Accounting Research, Volume 17, Number 1, Spring 1979, pp. 286-294.

McGhee, W., Shields, M.D., and Birnberg, J.G. "The Effects of Personality on a Subject's Information Processing," The Accounting Review, Volume 52, Number 3, July 1978, pp. 681-697.

Miller, G.A. "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," Psychological Review, Volume 63, Number 2, March 1956, pp. 81-97.

Payne, J. "Task Complexity and Contingent Processing on Decision Making: An Information Search and Protocal Analysis," Organizational Behavior and Human Performance, Volume 16, Number 2, August 1976, pp. 366-387.

Taylor, R.N. and Dunnette, M.D. "Relative Contributions of Decision-Maker Attributes to Decision Proc-

esses," Organizational Behavior and Human Performance, Volume 12, Number 2, October 1974, pp. 286-298.

Witkin, H.A., Oltman, P.K., Raskin, E., and Karp, S.A. A Manual for the Embedded Figures Test, Consulting Psychologists Press, Palo Alto, California, 1971.

Zmud, R.W. "Individual Differences and MIS Success." Management Science, Volume 25, Number 10, October 1979, pp. 966-979.