The Effect of Graphic Format and Cognitive Style on the Immediate and Delayed Interpretation of Complex Quantitative Data

J. Thomas Head
David M. Moore

Abstracf: This study examined the effects of graphic format and cognitive style on interptetation of quantitative data and of imagery instructions on recall. One hundred and twenty-three college students answered amount, static, and dynamic questions regarding the same data presented in one of four graphic formats: bar graph. linegraph, line-table chart. and table. The subjects also answered questions about trends and general concepts in the absence of the graphic under immediate and delayed imagery conditions. Subjects performance on the questions was in the order amount > statlc > dynamlc. There was no difference in results for the four graphic formats, but immedlate recall was better than delayed recall. The field independents performed better under the imagery condition and there was an interaction between cognitive style and type of graph. There was a modest correlation between the cognitive style and the scores on the dynamic questions.

Résumé: Les effets d'un format graphique et d'un genre cognitif sur l'interprétatlon des données quantitatives et le rappel des images instructives seront examinés dans cette étude. Cent-vingt trois étudiants universitaires ont répondu aux questlons statiques, dynamiques, et totales en ce qui concerne les données presentées dans un des quatres formats graphiques: une barre graphique, une courbe au trait un diagramme de table et trait, et un graphique. Les sujets ont aussi répondu aux questions concernant les concepts générales et les tendances a l'absence du graphique sous des images de condition immédlates et dilatoires. Ill y avait un ordre spécifique dans la representation des questions des sujets, tel que total > statique > dynamique. On ne voyait aucune difference dans les résultats des quatres formata graphiques; mals le rappel immédiat était meilleur que le rappel dilatoire. Il y avait une amélioration avec les Indépendants spécialisés sutte aux images de condition, et aussi une interaction entre le genre cognitif et le genre graphique. Les résultats ont mis en évidence une modeste corrélation entre le genre cognitif et les marques des questions dynamiques.

The rapid improvements in hardware and software for the production of computer graphics have provided the user with the capability to prepare graphic materials easily and quickly. As a result, graphics for instructional applications have shown a dramatic improvement and are approaching professional quality. The versatility provided by the software has made it possible to present numerical information in a multitude of chart formats. Most software packages allow the users to readily display the same data in a variety of different formata by a few simple keystrokes. However, educators and instructional designers still lack the empirical evidence to assist them in determining the "right" type of graphics to use in a given learning situation. The use of graphics in instruction has generally been recommended in the literature (e.g., Miller, 1969; Shostack & Eddy, 1971; Takeuchi & Schmidt, 1980). However, very few studies have been conducted to test the effectiveness of different types of graphics on the interpretation of quantitative data intended by the designer. Washburne (1927) investigated the effects of tabular, and graphic arrangements on recall. This study tested recall of specific amounts, as well as static and dynamic comparisons and rank ordering. Watson and Driver (1983) found that three dimensional graphic plots did not result in greater recall of information than did tabular presentation data.

MacDonald-Ross (1977) indicates that there are three questions to ask when developing quantitative data presentations: 1) What data to present; 2) Which format would be the best; and 3) How to present that format competently. The format of data which is presented is selected from a variety of possibilities. At times data presentation formats are selected with thought and sometimes without any rationale. "One is constrained by the data one is working with, and by the likely impact of the message on the reader. Having a purpose enables the writer to select between those alternatives which are legitimate and workable" (p. 361).

Watson and Driver (1983) state that the important variables to judge the value of a graphic presentation include understanding the data, prior knowledge, comprehension and "degree of appeal to the interest of user." The genera1 advantages of graphics in presentations have also been delineated by Watson and Driver (1983). Some of these advantages include the ability 1) to create interest in the user; 2) to aid in grasping relationships; 3) to save time when viewing masses of data, 4) to provide at a glance a comprehensive view of the relationship between different categories of information; and 5) to assist in analytical thinking. However, there appears to be a lack of research that supports the above claims. Benbasat and Dexter (1986) concluded that tabular reports led to better decision making and graphical reports led to faster decision makingwhen time constraints were low. However, a combined graphical-tabular report was found superior in terms of performance. Winn (1987, p, 192) stresses the importance of 'developing lines of inquiry into the learning strategies students use when working with graphic forms." It is important to discover how and what students learn from graphics. Are some graphics more effective than others? Are some types of information better presented by different graphic formats?

Designers and producers of visual materials must also be concerned with a number of considerations including the nature of the instructional task, the teaching and learning strategies to be employed, and the individual characteristics of the learner.

In his research, Witkin (1977) noted that certain individuals relied heavily on the outside environment for perceptual cues even as they conflicted with internal ones. Others were able to separate easily essential information from a surrounding visual field. The two orientations titled field dependence and independence, respectively, exist on a continuum, with individuals found at all points. Field dependent individuals tend not to add structure to visuals and accept the visuals as presented, because they do tend to fuse all segments of a visual field (e.g., a graph) and do not view the visual's components discretely.

Field dependent and independent individuals approach learning in different ways. Goodenough (1976) and Witkin, Moore, Goodenough, and Cox (1977) have reviewed the literature and offered several conclusions about learning and cognitive style. First, field independent individuals, being more analytic in approach, tend to *act* upon a stimulus complex, analyzing it when it is organized, structuring it when it lacks organization. In many instructional situations, the ability to analyze and structure aids in learning. The field dependent learner, however, takes a more passive approach, accepting the field as given, experiencing it in a more global, diffuse manner. This passive approach means that field dependent individuals tend to notice those cues in a stimulus field which strand out or are more salient. When the stimulus is arranged so that the salient cues are also relevant, then the field dependent person may experience little difficulty. In fact, if a learning task is clear, well-structured, and low in complexity, then there maybe no significant differences in learning by the two orientations. Field dependence is important because it involves perceptual and problem-solving abilities, structuring a stimulus field, breaking up or disembedding such a field, suppressing irrelevant information, and dealing with high information load, all of which are relevant in the interpretation of data in the graphic format. More specifically, it is of interest to determine if any of the various graphic formats help or hinder those individuals who are classified as field-dependent. These students may have difficulty processing complex visual information (i.e., as in a graphic format) unless it is presented in such a way as to compensate for specific processing deficiencies related to field-dependence (Head & Moore, 1989).

Head and Moore (1989) investigated the effects on interpretation of presenting numerical data in four different graphic formats: bar graph, line graph, table and line-table. Three types of quantitative recall were tested: questions dealing with specific amount, static, and dynamic comparisons (Washburne, 1927). Their results indicated that both main effects, type of graph and type of question, were significant, however, no interaction was present. This initial study was designed to be part of a continuing series of studies which increased the number of data points for each successive experiment. The rationale for increasing the amount of data was based on the prediction that as the number of data points become very large, the table charts would be ineffective and there would be interactions between the type of graph, type of question, and the amount of data presented. This would especially be predicted when subjects had time limitations, and for the questions which asked about changes in magnitude or general trends in the data. Both of these conditions would provide a better approximation to conditions in a classroom or business meeting.

Therefore, the purpose of this study was to determine if increasing the amount of data in different graphic formats, i.e., linegraphs, bar graphs, table, and line-table charts, affects the interpretation of quantitative information. The effects of these formats were tested by asking three types of questions: amount, static, and dynamic regarding the data presented. In addition, both immediate and delayed recall of relationships in the data were measured by asking questions in the absence of the stimuli. It was also of interest to determine if there was an interaction between graphic format and type of question and to determine whether cognitive style field dependence (FD), field independence (FI) interacted with the ability of the subjects to recall information in any particular chart format. This study was a ***partial replication and expansion*** of the study by Head and Moore (1989). The present study increased the amount of data presented by a factor of two and introduced the comparison of immediate and delayed recall in the absence of the graphic stimuli over the previous study.

More specifically, it was of interest to determine if there is any correlation between the various graphic formats and those individuals who are classified as field-dependent or field-independent. Field dependent students may have difficulty processing complex visual information (i.e., as a graphic format) unless it is presented in such a way as to compensate for specific processing deficiencies related to field-dependence.

The specific research questions generated for this study are as follows:

1) What is the effect of different chart formats on the interpretation of numerical data?
2) Is there any interaction between the type of graph and the type of questions asked?
3) What is the effect of increasing the amount of numerical data presented?
4) What is the effect of cognitive style on interpretation of numerical data presented in different chart-graph formats?

METHODOLOGY

Subjects

The subjects of this study were 123 college students enrolled in professional education classes or introductory educational psychology classes in a large, land grant university in the United States. The subjects were given the ***Group Embedded Figures Test*** (GEFT) (Witkin, Oltman, Raskin & Karp, 1971). The measure of field dependence used in this study was the Group Embedded Figures Test (GEFT), (Witkin, Oltman, Raskin, & Karp, 1971). It is avariation of the original Embedded Figures Test (EFT) which can be administered to groups rather than individually. Like the original EFT, the GEFT requires subjects to find a simple geometric figure embedded within a complex one. The GEFT consists of 25 such figures. It is divided into sections of 7, 9, and 9 items, with time limits of 2, 5, and 5 minutes respectively. The first section is for practice only and is not scored. The number of simple figures traced correctly on the second and third parts makes up the raw score which can range from 0 to 18. The more figures found and correctly traced, the more independent the subject is assumed to be. Since the manual for this test does not indicate recommended classifications for field dependence and dependence, the authors used the following system. Approximately the top 40 percent of subjects (15-18 were classified as field-independent, the lowest 40 percent of subjects (0-ll) were classified as field-dependent and middle 20 percent subjects (12-14) were classified as neutral. Several secondary analyses using the above classification of field dependence were also conducted.

Procedures

The subjects were randomly assigned to one of four treatments which were presented fictitious data in four different graphic formats: 1) bar graph, 2) line graph, 3) table, and 4) line-table chart. The data used to prepare the graphic stimuli were the same for all four treatments and were adapted from the Head and Moore (1989) study (see figures 1 and 2 for examples). The graphs and charts presented in this study contained twice the data points in comparison to the four types of graphs used in the 1989 study. These more complex graphs contained data at the maximum readability level for projected graphs.

The subjects were given a fictitious narrative and then shown a specific graphic stimuli, e.g., line graph on a 35mm color slide. Each treatment group was given questions on the content of the graphs and charts. There were four types of questions:

Figure 1.
Black and White Version of the Bar Chart Used as a Stimulus Slide.

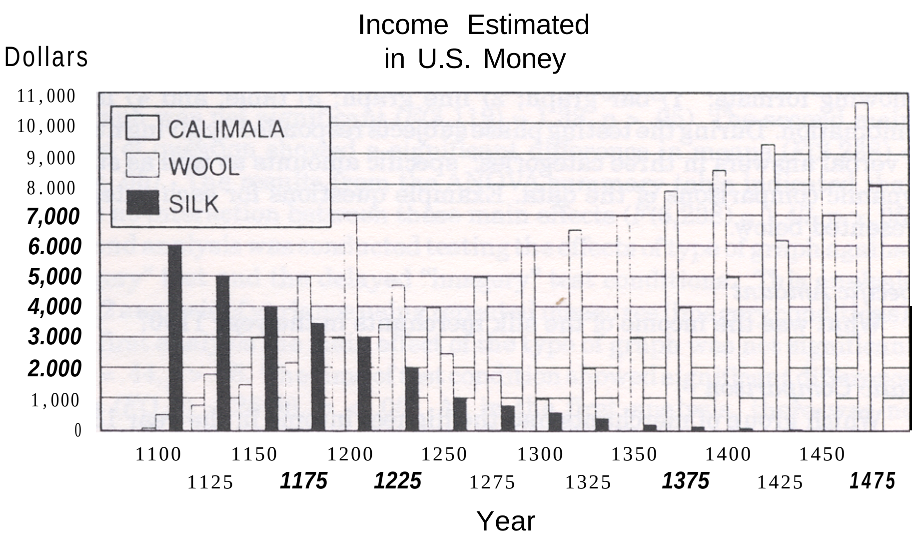
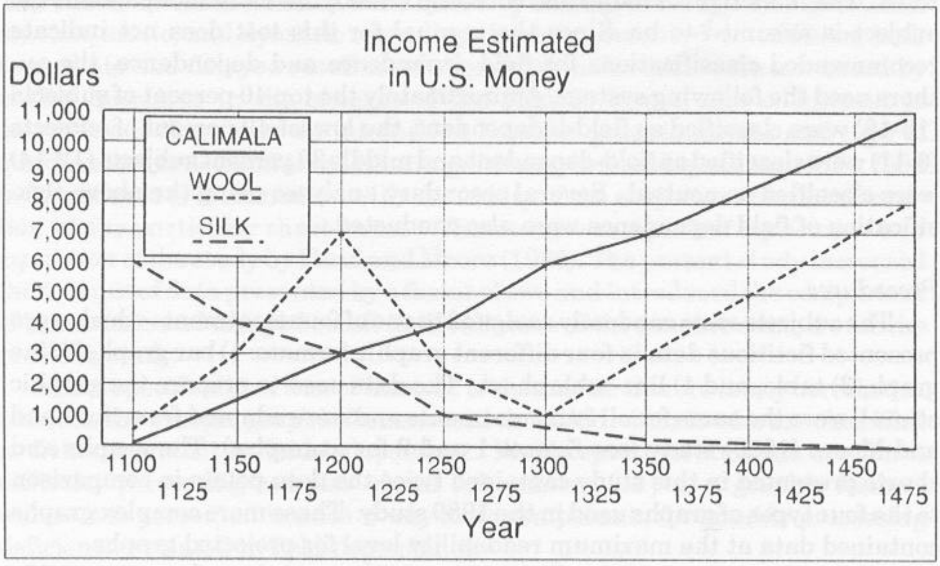


Figure 2.
Black and White Version of the Bar Chart Used as a Stimulus Slide.



1) Specific amount, e.g., how much, how many? 2) Static comparisons, e.g., which? 3) Dynamic comparisons, e.g., which increased (decreased) most rapidly? and 4) Imagery, which asked about trends and general concepts. All students in the treatment groups answered the same 56 questions (14 each in the above four categories).

The subjects were randomly assigned to one of four treatments which presented fictitious data in graphic form to alleviate any effect of prior knowledge. The fictitious data dealt with various European merchants income during the middle ages. The four treatments presented the same data in the following formats: 1) bar graph; 2) line graph; 3) table; and 4) line-table combination. During the testing phase subjects responded by giving numerical or verbal answers in three categories: specific amounts as well as static and dynamic comparisons of the data. Example questions for each category are presented below.

Specific Amount

What was the income of the silk merchants in the year 1100?

Static Comparison

Which group of merchants had the highest income in the year 1350?

Dynamic Comparison

Which group of merchants had the greatest increase in income between the years 1100 and 1200?

Imagery

Which group of merchants showed a sharp increase in income, then showed a sharp decrease, and finally recovered in the latter years of the time period described in this experiment?

In Part 1 of the experiment, all subjects were presented 42 questions (amount, static, and dynamic comparisons) with 7 seconds to respond to each question while looking at the treatment slide.

In Part 2, the subjects were then instructed to study the graphic on the screen for 60 seconds and form a mental image of the stimulus. The subjects were then asked 14 "imagery" questions about trends and general concepts with 7 seconds to respond to each question in the absence of the treatment slide. In the Delayed conditions, subjects were tested one week later using the same imagery questions without viewing the graphic.

Analysis

A two-way analysis of variance was used in which the independent variables were type of graphic and type of questions. The design was a 4 x 3 design based upon a mixed model and used a combination of between and within subjects methods (all subjects would respond to all types of questions). A second analysis was conducted using a two-factor repeated measure ANOVA to investigate effects of the types of graphs vs. the "imagery" questions (Part and the delayed "imagery" questions. The dependent variable was the test score which measures the interpretation of the quantitative data presentation.

RESULTS

A 4 x 3 analysis of variance with repeated measures was used to test the research questions concerning the type of graph and type of questions. The main effect means are found in Table 1 (see following page). The F ratio for the type of graph was not significant ($F(3,119) = 1.38$, $p > .05$). The second main effect type of question showed a significant difference in means 98.96, $p < .05$). The results from the ANOVA summary table indicated that there was no interaction between these main effects ($F(6,238) = 1.47$, $p > .05$.

A second analysis was conducted testing the effects of type of graph against the "imagery" test and the delayed "imagery" test conditions. This analysis used a 4 x 2 analysis ofvariance usingrepeated measures (imagery conditions). As in the first analysis the main effect of the type of graph was not significant ($F(3,101)= .44$,$p > .05$. The time of test condition showedsignificant difference in means ($F(1,3) = 25.36$, $p < .05$). As in the first analysis, there was no significant interaction between themaineffects ($F(3,l01) = 1.67$, $p > .05$). Table 2 (see following page) presents the mean scores of this analysis.

An additional analysis was conducted to determine if there was a difference in the earlier 1988 results (Head and Moore, 1989) and the present study

TABLE 1
Means by Type of Question and Graph

Type of Graph	Type of Question: Amount	Static	Dynamic	MEAN
Line	13.583	12.583	11.250	12.472
Bar	13.154	12.410	11.513	12.359
Table	13.792	13.000	11.708	12.833
Line-Table	13.611	12.417	10.806	12.278
MEAN	13.496	12.561	11.293	12.450

TABLE 2
Means by Imagery Questions and Type of Graph

Type of Graph	Imagery: Part 2	Delay	MEAN
Line	11.864	11 .000	11.432
Bar	12.074	10.185	11.130
Table	12.000	11.500	11.750
Line-Table	12.219	10.438	11.328
MEAN	12.057	10.733	11.395

across the dynamic question form. Using a one way ANOVA, the F ratio indicated that the 1988 results were significantly higher for the line-table condition ($F(1,58) = 33.61, p < .05$). Figure 3 (see followingpage) illustrates the difference of the means for the 1988 and 1989 study.

A series of two-way factorial analyses of variance were conducted. One used cognitive style and type of graph as independent variables with the "imagery questions" as the dependent variable. The main effect for cognitive style was significant $F(2,111) = 4.87, p < .01$ with an interaction between cognitivestyleand type of graph $F(6,111) = 2.31, p < .05$. See Table 3 for means.

Figure 3.
Percentages of Correct Responses for the Line-Table Chart Comparing 1988 and 1989 Experiments as a Function of Type of Question.

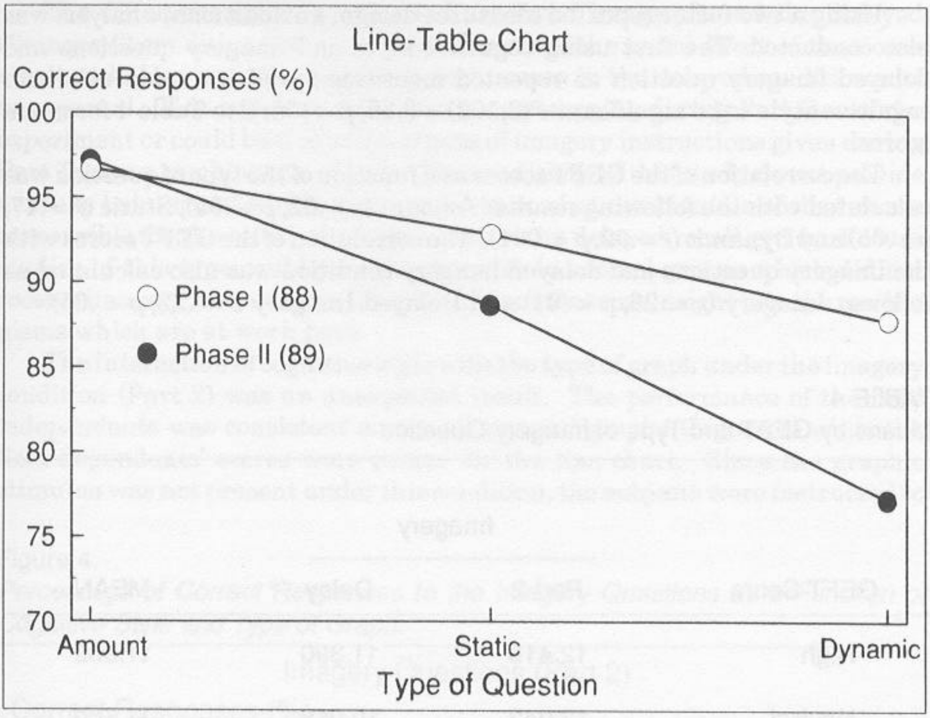


TABLE 3
Means by GEFT and Type of Graph

Type of Graph	High	Neutral	Low	MEAN
	GEFT Score			
Line	12.417	12.600	10.286	11.833
Bar	12.118	12.333	12.062	12.128
Table	12.545	12.000	11.333	12.000
Line-Table	12.600	11.583	12.357	12.167
MEAN	12.380	12.000	11.739	12.057

However, a second analysis using cognitive style and type of graph as independent variables with the scores on Part 1 as the dependent measure, found no significance for any of the variables with no interaction found.

Using a two-factor repeated measures design, an additional analysis was also conducted. The first using cognitive style and imagery questions and delayed imagery question as repeated measures found the main effect for cognitive style to be significant $F(2,102) = 3.36, p < .05$. See Table 4 for mean scores.

The correlation of the GEFT scores as a function of the type of question was calculated with the following results: Amount ($r = .02$, $p > .05$), Static ($r = .17$, $p > ,05$) and Dynamic ($r = .32$, $p < .001$). The correlation of the GEFT scores with the imagery questions and delayed imagery condition was also calculated as follows: Imagery ($r = .26$, $p < .01$) and Delayed Imagery ($r = .22, p < .05$).

TABLE 4
Means by GEFT and Type of Imagery Question

	Imagery		
GEFT Score	Part 2	Delay	MEAN
High	12.415	11.390	11.902
Neutral	12.042	10.958	11.500
Low	11.700	9.925	10.812
MEAN	12.057	10,733	11.395

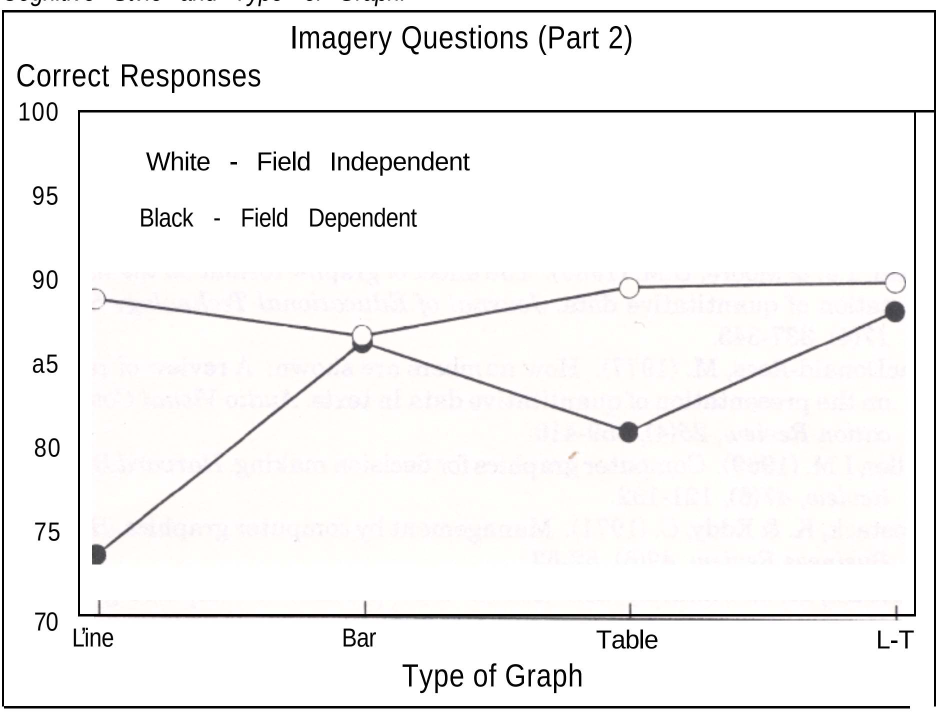
DISCUSSION

One of the main purposes of this study, which was an extension of a previous study by Head and Moore (1989), was to determine the effects of increased data complexity on the interpretation of quantitative data. The earlier study indicated that there was a significant effect for the type of graph. Increasing the amount of data did eliminate the main effect of type of graph found in the previous work. This was due primarily to the decreased performance of subjects in the table condition which resulted in no differences between the various chart types. Additional data obviously adversely affected the interpretation of graphic data used in this study The main effect for type of question was a predicted result because the amount, static, and dynamic questions obviously differ in difficulty in the order found in this study and in the earlier study

The difference in the scores for Part Two ("imagery") and the Delayed ("imagery") condition was predicted because of the usual effect of time on a recall task. However, the relatively high scores in the delayed condition was unexpected. This result could be due to overlearning during Part One of the experiment or could be due to the effects of imagery instructions given during Part Two or a combination of both. The conditions of this study do not provide a means to interpret which of these effects or what combination of the two are responsible for the relatively high scores in the delayed recall group. Future studies of this type could provide appropriate control groups which did not receive imagery instructions. This would provide some insight into the mechanisms which are at work here.

The interaction of cognitive style with the type of graph under the imagery condition (Part was an unexpected result. The performance of the field independents was consistent across all types of graphs (Figure 4) while the field dependents' scores were poorer for the line chart. Since the graphic stimulus was not present under this condition, the subjects were instructed to

Figure 4.
Percentage of Correct Responses to the Imagery Questions as a Function of Cognitive Stvle and Type of Graph.



form a mental image of the stimulus as a strategy which would aid them during the response stage. One possible explanation for the poorer performance of the field dependents would be based on these subjects lower ability to perform well under imagery instructions in this type of task. The low performance for the field dependents in the line chart condition needs further study to determine whether this type of graph presents unique problems for subjects with this cognitive style. This is of particular interest because the line chart should produce the highest scores for the types of questions asked in the imagery condition.

The correlation of GEFT scores with the type of question was in the order: dynamic > static > amount. This trend can be explained by the increasing difficulty of the task presented by the dynamic questions when compared to static or amount questions. The field dependents should not have any particular difficulty with the relatively easy questions in the amount or static categories, but would be expected to have more difficulty with the dynamic questions which do present a more demanding perceptual and cognitive task.

One other result which was of interest was the difference of the scores on the dynamic questions for the line-table condition as a function of data complexity (cf. Head & Moore, 1989 study). The group viewing the more complex graph (twice the data available) had lower scores, which is a predicted result given the difficulty of interpreting the dynamic questions.

REFERENCES

Benbasat, I. & Dexter,A.S. (1986). An investigation of the effectiveness of color and graphical information presentation under varying time constraints. *MIS* Quarterly, March, 59-81.

Goodenough, D.R. (1976). The role of individual differences in field dependence as a factor in learning and memory. ***Psychological Bulletin, 83, 675-694.***

Head, T.J. & Moore, D.M. (1989). The effect of graphic format on the interpretation of quantitative data. ***Journal of Educational Technology Systems*** 17(4), 337-343.

MacDonald-Ross, M. (1977). How numbers are shown: A review of research on the presentation of quantitative data in texts. ***Audio Visual Communication Review, 25(4),*** 359-410.

Miller, I.M. (1969). Computer graphics for decision making. ***Harvard Business Review, 47(6),*** 121-132.

Shostack, K. & Eddy, C. (1971). Management by computer graphics. ***Harvard Business Review, 49(6), 52-63.***

Takeuchi, H. & Schmidt, A.H. (1980). New promise of computer graphics. ***Harvard Business Review,*** 58(1), 122-132.

Washburne, J.N. (1927). An experimental study of various graphic, tabular and textual methods of presenting quantitative material. ***The Journal of Educational Psychology, 18,*** 361-376.

Watson, C.J. & Driver, R.W. (1983). The influence of computer graphics on the recall of information. ***MIS Quarterly,*** March, 45-53.

Winn, B. (1987). Charts, graphs and diagrams in educational materials. In D.M. Willows and H.A. Houghton (Ed). ***The Psychology of Illustration: Volume 1 Basic Research,*** 152-198, New York: Springer-Verlag.

Witkin, H.A., Moore, C.A., Goodenough, D.R., and Cox, P.W. (1977). Field-dependent and field-independent cognitive styles and their educational implications, ***Review of Education Research, 47,*** l-64.

Witkin, H.A., Oltman, P.K., Raskin, E., & Karp, S.A. (1971). A ***manual for the embedded figures test.*** Palo Alto, CA: Consulting Psychologists Press.

AUTHORS

J. Thomas Head is Director of Media Production Services at Virginia Tech University, 4 Patton Hall, Blacksburg, VA 24061-0124 USA.

David M. Moore is Professor of Education at Virginia Tech University