A VISUAL APPROACH TO INFORMATION SYSTEMS: AN INVESTIGATION OF THE MOMENTUM OF ACCOUNTING WEALTH CHANGES

by

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Dissertation submitted to the Faculty of

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

IN

BUSINESS ADMINISTRATION
with a major in Accounting (Information Systems)

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August 5, 1997
Blacksburg, Virginia

Key Words: Accounting, Momentum, Systems, Visualization

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(ABSTRACT)

This study investigates the relationship between three visual representations (two-dimensional, three-dimensional fixed, and three-dimensional rotatable) of multidimensional data, and the subjects' ability to make predictions based on the data. Output of a momentum accounting system was simulated and graphics were rendered based on that information. An interactive computer program was developed and used to administer the laboratory experiment and collect the results.

Subjects made prediction decisions based on the graphics produced for four companies. The companies were stratified based on size (high or low) and growth patterns (high or low). Each subject made predictions for one type representation for each of the four companies. Because of inconsistencies of the sample distributions for the different representations, nonparametric analyses were used to examine the data. The subjects using the three-dimensional data that could be rotated were found to provide the most accurate predictions. No differences between the treatments were found based on the subject's visual acuity, as measured by the Visual Vividness Imagery Questionnaire (VVIQ). The subjects using the two dimensional representations were found to take the least amount of time for their predictions.

ACKNOWLEDGEMENTS

The completion of this document represents a milestone that could not have been accomplished without the help of a large diverse group of people. First, I would like to thank my dissertation committee. I do not believe I could have assembled a better combination of individuals to provide input and guidance for the project. Drs. Brown and Sen, the co-chairs, allowed me to pursue the topic I was interested in, while helping me keep a connection with the mainstream of accounting and systems research. This document would not have been possible without their commitment to the completion of the project. Dr. Lowe's suggestions and comments over the years have kept me thinking about new ideas and refinements of the old ones. My exposure to Dr. Kleiner helped raise my expectations of myself. His perspectives from a field outside of accounting systems helped me see the common problems that occur in different disciplines and the cross-functional research opportunities that exist because of these issues. Dr. Tegarden has been extremely helpful due to his willingness to share his interest and research in the field of visualizations. On many occasions, when working on this project his ideas and support helped move the study forward. Additionally, his combination of theoretical and practical knowledge saved many hours of work and improved the quality of the dissertation. In addition to these five committee members, there were many other faculty members at Virginia Tech that asked thought provoking questions, or provided information that is greatly appreciated.

In addition to the faculty members, several other people on campus provided me a tremendous amount of help. Traci Hess (Ph.D. student in Management Science) and I jointly developed an interest in the field of accounting system visualizations. She helped me learn more about the topic, and understand the supporting areas, by her willingness to share knowledge obtained from her coursework and studies. After the background and proposal for this paper was developed, the experiment was created with the help of Jason Lockhart, Director of the Virginia Tech Multimedia Lab. Jason's ability to transform my ideas into an interactive, data collecting, aesthetically pleasing program, resulted in an experiment that was well beyond my original expectations. Throughout the process of developing this document and its predecessors, Christine Hughes, an Instructor in the Virginia Tech English Department, read and edited many sections and drafts. Each of her suggestions improved the quality of the document and made it easier for you to read. I am indebted to each of these people for sharing their talents; I am gratified that I can count them as friends. There are countless other people that have been friends and associates while at Virginia Tech. While some of these people did not directly impact this document, they did help improve the quality of my life and indirectly improving the quality of my work. I am appreciative for this community of people.

Finally, I would like to thank Susan, my wife. She provided support throughout the entire educational process at Virginia Tech. When I considered entering the Ph.D. program, she helped eliminate the obstacles; without her, not only would the completion of this dissertation been impossible, but the beginning of the process would not have occurred. For her sacrifices, love, and support, I will always be indebted.

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CHAPTER 1

INTRODUCTION

> "The whole activity of the visual system, at whatever level we choose to study it, is designed to find significant discontinuities, pockets of order in the ordinary tumult of light."[1]

1.1. Research Purpose

It is almost universally accepted that a primary purpose of an accounting information system is to accumulate and communicate a firm's economic data for use by those making decisions regarding the firm. Over the past several years, technological advances and business environmental changes have created an openness in attitudes toward electronically collecting and presenting data for analysis. These changes have driven the automation of accounting systems to a point that has made the manual collection and presentation of data almost obsolete. There has been little research to investigate the application of technological advances in presentation graphics to decisions made with accounting data. This study investigates the relationship between three visual representations (two-dimensional, three-dimensional fixed, and three-dimensional interactive) of complex accounting data, and the subjects' ability to make predictions based on those data.

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[1] From Visualization: the second computer revolution (Friedhoff & Benzon, 1989).

1.2. Momentum Accounting: A Complex Problem Space

It has been proposed (Ijiri, 1982, 1986, 1990) that there should be an extension of double-entry accounting that would consider a third dimension of accounting data -- the time effect of accounting entries. This extension, commonly referred to as “momentum accounting," uses the relationship between time and traditional accounting information. As such, it may provide more information on which decisions could be based (Ijiri, 1989). This information would include information relating to the wealth of an organization and its corresponding rates of change (Ijiri, 1982, 1986). This information could be provided on a continuous basis rather than on a quarterly or annual basis. One of the main criticisms of momentum accounting is its higher level of complexity (extension to a third dimension, i.e., recording expected future effects), when compared to that of traditional double-entry accounting (Fraser, 1993).

Momentum accounting increases the complexity of an accounting system by expanding on the single-dimension stock (assets and liabilities) and two-dimensional flow (revenues and expenses) concepts, by adding a third dimension (time) and, therefore, a corresponding third component of each entry. This study focuses on the output of a momentum accounting system rather than the details of journal entries and the recording of transactions. This approach is taken because there is no benefit in accumulating and reporting information with a system if decision-makers cannot understand the information generated by the system. In momentum accounting, decision-makers would consider wealth, the rate of wealth change (momentum), and the rate of momentum change (impulse) in wealth.[2]

This research includes a mapping of the momentum accounting concepts to their underlying physical science concepts; this should provide decision-makers with a better understanding of wealth and its components. With this mapping in place, there should be a clearer understanding of how the underlying concepts relate, and how they have been visually represented. Finally, this study investigates the possibility of using visualizations to assist in understanding the information generated by a momentum accounting system.

1.3. Accounting System Advances

Using innovative ideas and automation techniques to address accounting issues is a common concept within the field of information systems (Martin, 1996; Woodward, 1996). Over the past two decades, due to this proliferation of computers and automation of systems, it is now possible to provide decision-makers with accounting information that previously has not been cost-effective to produce. Despite significant advances in financial reporting and accounting systems, these systems have generally not kept pace with the available information technology, although there have been attempts to move the accounting profession forward into new technology (Martin, 1996; Woodward, 1996). Elliot (1995) suggests that if accountants want to maintain the value of their services, they will have to keep up with technological advances.

[2] Currently decision-makers are focused on earnings and therefore managers tend to "manage" earnings (see Dechow, Sloan & Sweeney 1996). With the focus on wealth, decisions that manipulate earnings would have reduced significance.

Even with today's technological advances, the complexity of implementation has limited interest in the development of momentum accounting systems. Currently, there are no systems with momentum accounting capabilities commercially available.[3] Because of this lack of general use, this research used financial market information to simulate the information that might be provided by an actual momentum accounting system.

1.4. Visualization Advances

The "most basic visualization" has been described as "simply plotting points of data on a piece of graph paper" (Wolff & Yaeger, 1993, p. 89). In the early 1980's as personal computers became more abundant, this plotting task was refined by using spreadsheet programs with graphic capabilities. As the computer industry expanded, the increase in power and decrease in cost for desktop and network PC's has facilitated the development of sophisticated programs that allow computer users to easily produce visualizations[4] of data from a variety of sources. Historically, to develop a graphic representation, one had to create and program routines based on geometric formulae for each component of a graph; this limited all but a few highly trained individuals from the visual exploration of data. This also prevented the rapid change of visualizations to adapt to individual preferences for data presentation. The tools[5] that are available today include many graphic libraries that include

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[3] Although CEC-Services (1997) has indicated its intent to produce, by mid-1997, an accounting class library that supports triple-entry bookkeeping, one would expect at least another year prior to any implementation of such a system.

[4] Keim, Bergeron and Pickett (1995, 10) indicate that a visualization system helps "transform numerical data of one kind or another into pictures in which structures of interest in the data become perceptually apparent." Therefore, a visualization can be described as a picture that visually represents relationships within data.

[5] See Section 3.3.1. for more information regarding the currently available tools.

computer language code for standard routines, 4GL programming languages that aid programmers in code generation, and point-and-click data analysis tools. The outputs from the programs vary from basic two-dimensional graphics to virtual reality systems. Even with the relative simplicity with which today's tools may be used to transfer data to graphical representations, there is still some inherent complexity that exists. The typical computer user may be able to generate simple graphics, but patience and practice is required to develop useful multidimensional representations. Although commonly available, today's visualization tools have primarily been used to increase the understanding of phenomena within the realm of the physical sciences (Tufte, 1990; Wolff & Yaeger, 1993) and, more recently, for entertainment purposes.[6] Apart from engineering and the physical sciences, research has been limited. There have been few studies in the business and accounting areas beyond the traditional "graph versus table" literature.[7] This lack of coverage can be attributed to the complexity level and rate of change of the newer visualization software tools (Woodward, 1996). These new visualization tools can be used in the context of accounting information to match the dimensionality of the representation with the dimensionality of the data, possibly increasing the understanding of complex accounting concepts and information (Cooper, 1990; Vessey, 1991).

[6] One only has to look at currently available video games and "action" movies to see the adaptation of the visual technology to this field.

[7] Vessey (1991) provides a summary and analysis of a significant body of the "graph versus table" literature.

1.5. Method, Task and Variables

When developing the visualizations to represent data, one must consider the wide spectrum of options within data representations. The range varies between Wolff and Yaeger's (1993) "most basic" plot (as described in the previous section) to their discussion of 3-D animations.[8] This range provided the parameters for the development of graphics that represented the information provided by momentum accounting. The development of representations included simulating a function for wealth, momentum (the first derivative of the wealth function), and impulse (the second derivative of the wealth function). Halliday, Resnick and Walker (1993)[9] provided the basis for the first visualization used in the experiment, a two-dimensional representation that used three lines (each being one of the above described functions) to convey the momentum accounting information; the x-axis represented time, while the y-axis concurrently represented wealth, momentum and impulse. The second visualization was based on a 3-dimensional linear plot;[10] the graphic generated was a static three-dimensional representation, with points plotted from the individual momentum accounting functions. In this visualization, the x-axis represented time, the y-axis momentum and the z-axis wealth. Impulse was represented by application of a relative color scale to the line formed through the plotting of the (x,y,z) coordinates.[11] The third

[8] Wolff and Yaeger (1993, 146) indicate that "Surface rendering and 3-D animation techniques [that} once were the tools of computer graphics specialists and a small circle of highly expert software engineers are now available as a part of relatively low-cost commercial software packages on personal computers."

[9] Halliday et al. (1993) used a similar graphic to display velocity and acceleration during an automobile crash.

[10] An example of such a plot is included in Wolfram (1996, 945).

[11] An example of using color as a fourth dimension can be found in Matlab (1996).

visualization was identical to the second except users of the third had the ability to rotate their representation and view the interaction of the data from various angles.[12]

After the establishment of the “momentum accounting visualizations," a laboratory experiment was conducted to test the differences between the visualizations with regard to subjects’ ability to make predictions of wealth. Wealth is a concept key to momentum accounting (Ijiri, 1982, 1986). Each subject was given a series of representations of information in one format and asked to make predictions on each representation in the series. The two primary independent variables in the experiment were representation type (manipulated – three levels) and visual acuity[13] (measured – two levels)[14]. Visual acuity was measured after the experimental decisions were made through the use of the Visual Vividness Imagery Questionnaire (VVIQ).[15] The dependent variables included the accuracy of the subjects’ predictions (measured relative to predictions based on the model used) and the time to complete a prediction. Examination of the results include prediction accuracy based on the manipulation of representations, prediction accuracy based on visual acuity, and time to predict based on the manipulation of representations.

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[12] Image rotation is discussed in section 2.3.3.

[13] Marks (1973) used visual acuity as a measure of an individual’s ability to mentally “see” and recall objects.

[14] The actual scale is continuous, but for the purposes of this research, the scale was stratified into thirds; the top and bottom scoring thirds were classified as high visual and low visual, respectively.

[15] The specific form used in this experiment was obtained from Marks (1973).

1.6. Implications of this Research

By applying new visualization tools to a complex accounting problem, this study provides contributions in accounting and information systems. First, it should move forward the establishment of visualization research into the accounting domain. To date, research in accounting visualizations has been limited to simple graphics (Anderson & Kaplan, 1992; Anderson & Reckers, 1992; MacKay & Villarreal, 1987; Stock & Watson, 1984). Research in other fields has indicated significant benefits (such as a better understanding of data relationships) may accrue to the users of visual representations (Wolff & Yaeger, 1993); applying similar concepts and tools to accounting may also yield a better understanding of the increasing volume of accounting data. Visualizations may provide a method to improve decisions by increasing the user's understanding of the data. The second contribution is the development of a method to increase the understanding of a complex accounting issue, momentum accounting. This can be accomplished by presenting the momentum accounting information in a format that recognizes and focuses on the relationships between wealth and the underlying components of the change in wealth. If visualizations can aid users in understanding this complex concept, they may later be applied to other complex accounting ideas generating a more complete understanding of those concepts.

1.7. Organization of this Dissertation

The basis of this research is the application of certain visual representations to an accounting-based problem space. Chapter 2 develops the theoretical basis for this application, describing historical studies of visualizations in decision-making in general and within the domain of accounting. The chapter continues into a discussion of momentum accounting and its ties to traditional accounting concepts, organizational operations and the physical sciences. Chapter 2 then moves into a discussion of tools and concepts that are available for visualization, including those used in this research. Finally, the hypotheses are developed based on the foundation formed in Chapter 2.

Chapter 3 describes the research methodology, including a detailed description of the variables and the experiment used to obtain data to test the hypotheses developed in Chapter 2. Chapter 4 discusses the statistical analysis that was used to test the hypotheses, and finally, the results of the statistical analysis, including the tests of hypotheses, are discussed in Chapter 5. This final chapter concludes with a discussion of a future direction for this course of research.

CHAPTER 2

LITERATURE REVIEW AND THEORY DEVELOPMENT

2.1. Visualizations in Decision Making

2.1.1. Behavioral Perspective

The behavioral disciplines have had many research studies relating to the topic of visualization (Colet & Aaronson, 1995; Cooper, 1990, 1995; Schkade & Kleinmuntz, 1994). This interest is in part due to the recognition that one's experiences are based on observations from a three-dimensional world (Cooper, 1990). From this, it is reasonable to conclude that if one's experiences are from a 3-dimensional world, representations on which he or she might make decisions may be understood better in that format. Another basis for the behavioral interest in the area relates to visualizations' usefulness in recognizing relationships among data. It can be used as a tool to direct the process of mathematical modeling when investigating these relationships (Colet & Aaronson, 1995). Yu and Behrens (1995) developed their framework of using visualizations in statistical analysis to assist in "balancing noise and smoothing in statistical analysis" (p. 264).

Beyond the general statistical analysis uses of visualizations in psychological literature, numerous studies have investigated human interactions with visualizations (Cooper, 1990, 1995; Lohse, Biolsi, Walker & Rueter, 1994; Schkade & Kleinmuntz, 1994). Cooper looked at the connection between two-dimensional and three-dimensional views of an object (1990) and the concept of mental imagery (1995). The 1990 study suggests that when confronted with two-dimensional representations of structural objects, individuals will mentally create a three-dimensional representation of the object. This research is significant in reporting the mental connection between two-dimensional and three-dimensional representations. In addition to establishing this connection, relating to the dimensionality of representations, psychological research has investigated the decisions made based on the type of representation. Schkade and Kleinmuntz (1994) found a significant effect on the decision process based on the information format[16] used during information acquisition. This research leads one to believe that to ensure the "best" decisions, one needs to present the information in the "best" format. This area has received attention recently, relating to the selection of the visualization for a specific task.[17] For any study of visual representations to be beneficial, the proper (or most useful) representation of the data must be selected.

One attempt to classify visual representations included eleven general categories: structure charts, cartograms, maps, graphic tables, process diagrams, icons, time charts, network charts, pictures, tables and graphs (Lohse, et al., 1994). Based on the type of data presented and the decisions to be made, these authors suggest that these categories will suffice for visual representations. Each category has positive and negative characteristics when representing different types of data. Even after the selection of the representation category, there are a large number of decisions related to the actual information representation. To optimize the effect of a visualization, one must look at the details of a representation and ensure that the data is revealed rather than obscured (Tufte, 1983). These details may incorporate motion, color, or three-dimensional effects into the visualization. As previously described, the presentation of information to the decision-maker will affect the outcome of the decision. This best format concept is supported by the cognitive fit model (Vessey, 1991). The model suggests that there are different types of problems, processes to solve the

[16] Formats may include textual information, graphics or any other method of information conveyance.

[17] For a cognitive psychology perspective, see Vessey (1991) and Umanath and Vessey (1995).

problems, and representations of the problems; when the components "fit," problem solving speed and accuracy will be improved (Vessey, 1991). Vessey's study (1991, p. 223) concludes that "matching the problem representation to the type of task to be solved results in improved decision-making performance." If inconsistency exists among these components, it has been shown that decision-makers sometimes "translate" an information format into one with which they are more familiar and base their decision on the new format (Jones & Schkade, 1995). When decision-makers translate, they are thereby choosing their own representation. It has been shown that "permitting decision makers complete freedom in choosing their own problem representation(s) will not necessarily lead to improved performance" (Vessey, 1991, p. 236). Although allowing the information user a choice in the representation selection may not help in his or her understanding the data, the proper use of scientific visualization[18] techniques may help the individual effectively understand and encode the data (McCormick, DeFanti & Brown, 1987).[19]

In addition to format research, significant psychological research concerns the subject that uses visualizations on which to base decisions (Childers, Houston & Heckler, 1985). Differences in an individual's imagery ability have been linked to the individual's ability to learn and solve problems.[20] One tool that is available to study and control for visual differences between subjects is the Visual Vividness Imagery Questionnaire (VVIQ).[21] The VVIQ poses four verbal descriptions of images to the subjects and makes four statements about each image. The subjects are then asked to rank the clarity of the image in their "mind's

[18] Yu and Behrens (1995) define scientific visualization as "the process of exploring and displaying data in a manner that builds a visual analogy to the physical world in the service of user insight and learning" (p. 264).

[19] One should be cautious when using visualizations to prevent distorting or obscuring information (Tufte, 1990).

[20] Marks (1989) provides a thorough review of the literature in this area.

[21] The specific form used in this experiment was obtained from Marks (1973).

eye." The tool was developed by refining and modifying Betts' Questionnaire (Betts, 1909). Betts' Questionnaire measures the visual ability differences among individuals (Marks, 1973; Sheehan, 1967). Because the VVIQ consists of self-reported measures, some concern exists regarding the tool's validity; however, several studies have used the VVIQ to measure image-processing skills, and it is generally accepted within psychological research to be an internally consistent tool.[22]

In summary, behavioral theories suggest that multi-dimensional visualizations should be useful in decision-making; such visualizations can help in recognizing relationships among data. If these visualizations fit the problem and problem solving process, the speed and accuracy of the problem solving should benefit. Another factor in problem solving from visualization representations is the difference in visual acuity among individuals. One effective tool to measure this difference is the VVIQ.

2.1.2. Accounting Decisions

Cognitive science plays an important role in understanding the decision making process in the field of accounting.[23] This role continues as one expands into accounting based visual representation research. The majority of the research in accounting visualizations has been related to report format and presentation. The formats for most research projects differ significantly, although one theme continues throughout the literature; the presentation format of information affects the decisions that are made (Anderson & Kaplan, 1992; Anderson & Reckers, 1992; MacKay & Villarreal, 1987; Stock & Watson, 1984). Much of the past research is based on two-dimensional graphs. One may assume that this is due, in fact, to the

[22] See White, Sheehan and Ashton (1977) for a review of these studies.

limited tools available for multi-dimensional representations. Generally, most of the multidimensional research was performed using Chernoff Faces.[24] Results indicate that representation format may improve decisions (MacKay & Villarreal, 1987; Moriarty, 1979; Stock & Watson, 1984); however, MacKay and Villarreal (1987, 536) indicate that using faces may reduce the content validity of a visualization and, as such, limit its usefulness as a decision aid. With today's technological advances, using most desktop computers one can represent multidimensional data by generating complex graphics rather than by limited formats such as the faces.

Many problem spaces have been investigated relative to accounting information. Areas of interest include financial forecasting and time series information (Bouwman, Frishkoff and Frishkoff, 1995; Carbone & Gorr, 1985; DeSanctis & Jarvenpaa, 1989) and auditors' effectiveness (Kaplan, 1988; Moriarty, 1979). Goldwater and Fogarty (1995) looked at cash flow predictions based on the format of information presentation. This is significant not only because of the visualization aspect of the research, but also because their topic indicates that decision makers view information that is not based on accrual accounting as relevant to the decision making process.

Recent publications have recognized the significance of visualizations of non-accounting information in annual reports (Graves, Flesher & Jordan, 1996; Preston, Wright & Young, 1996). If decision-makers obtain useful information from this source, there may be an opportunity to provide them with similarly easy to comprehend and use financial information.

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[23] For a detailed analysis see Dillard (1984) and Libby and Lewis (1982).

[24] Chernoff used facial characteristics as variable representations for multivariate analysis (Chernoff, 1973).

In summary, many types of decisions have been used to examine representations of accounting information. Included in these decision-types are predictions of future results. With regard to these accounting based decisions, representation format has been shown to be important to the decision-making process. In some instances, two-dimensional representations have been shown to assist in superior decisions over tabular presentation of data. Multi-dimensional representations (Chernoff Faces), although a limited form of representation, have been shown to improve decisions relating to multi-dimensional data.

2.2. Momentum Accounting

2.2.1. Background

Momentum accounting grew out of a literature that suggests double-entry bookkeeping is not the sole solution to all accounting information needs (Ijiri, 1986). Ijiri (1986) indicates that a logical extension of double-entry bookkeeping would be a triple-entry system that includes a set of “force” accounts to reflect the time that an activity will affect the company. The triple-entry extension was formalized by Ijiri (1986).

To understand the foundation of triple-entry bookkeeping (also known as momentum accounting), one must look at the components of single and double-entry bookkeeping. Single-entry was based on the “stock” accounts of an organization. In today’s terminology, the stock accounts are typically assets and liabilities. When moving to a double-entry system, the change in a stock account is identified as a flow. The flows may be represented by revenue or expense accounts (Ijiri, 1986). This is intuitive in today’s environment when one relates the concept to the statement of cash flows. In that statement, a change in an asset or liability account is reconciled to changes in income, an aggregate of revenues and expenses. The extension of double-entry to triple-entry bookkeeping suggests that the accounting system include a new dimension that looks at the change in *flows*. This can be done through the introduction of a new set of accounts that measures the *rate* at which flows are changing (Ijiri, 1986).

The basic component of momentum accounting is the wealth of the organization (the net value of the stock accounts). The wealth of an organization is described as the assets of the organization less the organization's liabilities (Ijiri, 1986). This can also be described as the equity of the organization. Within the realm of double-entry accounting, a change in wealth is equal to the income for a specified period of time. By using a series of formulae, one can describe the relationship among the momentum accounting concepts of wealth, momentum, and force. Momentum is described as the first derivative of wealth with respect to time, and force is described as the second derivative of wealth with respect to time:

$$M = \delta W/\delta t \quad (1)$$

$$F = \delta^2 W/\delta t^2 \quad (2)$$

(Where M = momentum, W = wealth, F = force and t = time) (Ijiri, 1986). Momentum can also be described as the rate of change of wealth. Accounting momentum is measured in terms of dollars per period of time. For example, if an organization's wealth changes $1000 each month, the momentum could be described as approximately $250/week, $1000/month or $12,000/year. The difference between this concept and traditional income is that income is for a specific period of time (e.g., for the year ending 12/31/97). A description of impulse would be the rate at which momentum is changing. The measurement of impulse is in dollars per period of time squared. An impulse generates a change (positive or negative) in momentum; an example would be the hiring of a salesperson. A new salesperson should generate sales in excess of cost for the period of time the individual stays in a sales position, increasing momentum, the rate at which the company is increasing wealth. One would expect this action to increase the rate that the company increases wealth.

The unique representation of accounting information in terms of physics has provoked some criticism. One critic of this model questions the increased information complexity (including predictive issues) and the unknown benefits to decision-makers (Fraser, 1993).[25] The same author also indicates that it may be difficult to empirically test the model. Increased complexity is a valid concern. Currently, no momentum accounting systems are in use because of this complexity.[26] A "complete" implementation of momentum accounting should include the recording of all events (impulses) that have an effect on the wealth of an organization. When accomplished, this will have the effect of creating a de facto market value accounting system. Market value, or firm value, is equal to the discount of future cash flows[27] for an organization; a change in momentum impacts those future cash flows and thus the firm's wealth. Even with today's advanced technological capabilities, there are limitations with regard to recognizing these impulses and estimating the strength and duration of each impulse. This is especially true when critical impulses may be external environmental factors for the organization.

Recognition and estimation of wealth change effects may be difficult, but not impossible. Historically, accountants have worked through estimation in various ways; arbitrary lives have been assigned to assets when actual lives were unknown (goodwill and

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[25] Fraser (1993, 151) questions the usefulness of momentum accounting and indicates benefits are "at best problematic." He also suggests that if useful information is provided by triple-entry bookkeeping it "is likely to result by accident, rather than by design." (p. 157)

[26] Although CEC-Services (1997) has indicated its intent to produce an accounting class library that supports triple-entry bookkeeping by mid-1997, one can expect at least another year before any systems are actually implemented.

[27] Ohlson (1995) identifies this concept "standard in neoclassical models of security valuation."

[28] Ohlson (1995) identifies this concept "standard in neoclassical models of security valuation."

fixed assets). In some cases (such as research and development) expenditures are simply expensed because the estimation is difficult. Other methods of valuation include external confirmation (receivables and payables) and review of sales frequency and pricing (inventory). For liability estimation, auditors rely on attorneys' representations to determine if an item needs to be recorded, and at what amount. Although momentum accounting is not in use, if the required estimating procedures are developed, it is conceivable that an evolution of accounting systems to include the time effect of transactions is possible. This process will not occur instantaneously, but will require much thought, effort, and expertise to progress. This research ignores the details of implementation and assumes if the information provided by the system is beneficial, the demand from decision-makers will ensure an effective implementation. However, the study does investigate a method of providing momentum accounting information to decision-makers and, empirically tests the effectiveness of the portrayal of this information.

Prototype examples of the momentum accounting concept exist within the accounting literature. Ijiri (1989) gives detailed examples of transactions and financial statements that reflect wealth, momentum and impulse information. Blommaert and Olders (1995) use financial statements prepared based on momentum accounting concepts to investigate managers' use of the additional information provided in their decision making process when predicting earnings for a future year. Their findings indicate that subjects using momentum accounting statements use the information to make more accurate predictions of earnings than do those using traditional financial statements. Their study looked at the inherent usefulness of momentum accounting information, while the current study used momentum accounting information to test visualizations. The focus of the current research is visual representations of actual market data, while Blommaert and Olders (1995), use a more traditional financial statement format for their research of hypothetical data.

2.2.2. Momentum Accounting Concepts in Accounting Research

2.2.2.a. Firm Valuation

The value of a firm is closely associated with momentum accounting concepts. This dissertation relies heavily on the relationship between the wealth of an organization at two points in time. The relationship description comes from Ohlson's application of clean surplus accounting (Feltham & Ohlson, 1995; Ohlson, 1995). Under clean surplus accounting, a firm's book value at a point in time is equal to the book value at a previous point of time plus any income, less any dividends between the two points:

$$bv_t = bv_{t-1} + x_t - d_t \qquad (3)$$

(Where bv = book value, x = earnings, d = dividends and t = date) (Feltham & Ohlson, 1995). A distinction has also been drawn between *conservative* and *unbiased* accounting. Unbiased accounting is the term used to describe the case where goodwill approaches zero; this is opposed to the description of conservative accounting that suggest that the expected value of goodwill will be greater than zero (Feltham and Ohlson, 1995). The current study used the unbiased approach, because under conservative accounting, the creation of economic goodwill is ignored with respect to the book value of the company (goodwill = market value of the firm - book value of the firm). Goodwill is reflected in the market value of the company (i.e., security price). If there is an influence (internal or external to the company) that facilitates the creation of goodwill, it should be considered when decisions are made with respect to a company. One of the unbiased accounting propositions of Feltham and Ohlson (1995, p. 711) indicates that the difference in expected value of a stock between two dates should equal earnings (if dividends are ignored, as is the case for growth companies) over the long term. This proposition is equivalent to the momentum accounting implementation of a market value based system, where the measurement of market value is possible at any two points in time.

2.2.2.b. Earnings Forecasts

The past thirty years has seen considerable research in the area of the behavior of earnings over time. Many authors have looked at the forecasting ability of earnings and the relevance of accounting information to investors (Ball & Brown, 1968; Beaver, 1970; Foster, 1977; Ou & Penman, 1989; Richardson, Cunningham & Brown, 1995; Simmons & Gray, 1969).[29] The bulk of the evidence suggests that annual earnings follow a random walk series. The theory of a random walk of earnings indicates that the best predictor of earnings is the prior period earnings plus some random error term (Beaver, 1970).

Studies of the predictive ability of quarterly data provide significant information that serves as background for this research (Bathke & Lorek, 1984; Collins, Hopwood & McKeown, 1984; Dhaliwal, Kroner & Lee, 1995; Foster, 1977;). Foster (1977) looked at the time-series' properties of quarterly accounting data. He indicated that by 1976 there had been over 70 empirical studies using quarterly accounting data. Foster's study examined six models within the framework of determining their "ability to forecast future values of the same series" (Foster 1977, p. 17). He concluded that quarterly data do not emulate annual financial data, but rather have seasonal and adjacent quarterly components. These results indicate a reduction of the time period may help decision-makers understand and forecast with more accuracy. The introduction of momentum accounting, by allowing a *continuous* function of wealth changes, can provide a better understanding of the "turns" in momentum, and therefore

[29] A "review and synthesis" of accounting information/stock valuation model research through the mid 1980's is available in Atiase and Tse (1986).

increase the reliability of forecasts over those relying upon discrete quarterly or annual data. It should be noted that if this reduction in the length of the period increases the usefulness of data, it follows that continuous data may provide the most useful data possible.

To enable the application of earnings' research to momentum accounting and the related wealth concepts, one must be able to link wealth with earnings. Beaver (1970, p. 66) describes income as the difference in a firm's wealth between two points in time. Beaver, Lambert and Ryan (1987) used changes in firm value to predict earnings. When defining a firm's value as the market value (share price times number of shares outstanding), one can assert that income earned by a shareholder between the two points in time is the change in the market value. Feltham and Ohlson (1995) have developed models supporting the relationships among market values and operating activities for firms. They have shown within their clean surplus accounting model (using the unbiased accounting approach), that the change in firm value is equivalent to the change in book value, which is equal to the income for the firm (Feltham & Ohlson, 1995).[30] Using this approach, one can argue that much of the literature that relates to the prediction of income may also be adapted to the prediction of wealth. Extending the random walk model to momentum accounting should yield a model such that wealth at a certain time t, would be equal to the wealth at time t-1, plus earnings for the period beginning at t-1, plus a random factor:

$$W_t = W_{t-1} + E_t + r \qquad (4)$$

(Where W = wealth, E = earnings and r is a random factor).

[30] This assumes no dividends paid by the firm.

2.2.3. Relevance of Momentum Accounting within the Organization

Organizations have moved through three general eras with respect to technology (Toffler, 1980). Elliott (1992) associates each of these periods with the information required for decision-makers. Single-entry accounting was satisfactory during the agriculture era, when labor was the primary physical technology. Because organizations were relatively simple, recording and tracking assets and liabilities were much less arduous tasks than in today's complex environment. During the industrial era as factories were built and companies expanded (based on the usage of machinery), organizations became more complex. With the movement to professional management, and monitoring the activities of that management, more information was needed for owners and creditors to make decisions. Double-entry accounting met the challenge and provided income information by the examination of the changes in flows of assets and liabilities.

During the industrial period, the information requirements remained relatively stable. Toffler (1980) and Elliott (1992) suggested that today, we are in the information era. Product life-cycles have been reduced drastically.[31] The computer is playing an ever-increasing role in the provision of information for the management of organizations (Elliott, 1992). This information-rich environment is ripe for an accounting system that recognizes the importance of time and rate of change when providing information to decision-makers.

Consistent with the dynamic nature of today's businesses, momentum accounting is built on the theory that organizations are not operating in a static state. The earth, for example, a body moving around the sun at approximately 30 kilometers per second, is apparently static when viewed by the human eye. Similarly, organizations are moving through their "financial life" at some rate that cannot be easily measured by merely looking at the year-

[31] The reduction of the "cycle time" has become increasingly important to industrial productivity. For additional information in this area, see FedEx Center for Cycle Time Research (1997).

end or even quarterly financial results. Each decision, either internal to the organization or externally affecting the organization or its environment, has some impact on the wealth of the organization. For example, adding a salesperson to an organization's sales force will generate a certain amount of future sales that have some current discounted value. The difference between this value and the discounted cost (direct and indirect) of the salesperson yields the immediate net change in wealth of the organization. Ijiri (1986) defines these organizational or environmental changes as impulses. Impulses affect the rate at which the organization earns income, therefore affecting the current wealth of the organization.

Impulses can cause immediate changes within an organization, but many actions that occur are irreversible within the short term. Long term assets and liabilities frequently cannot be acquired (or disposed of) and contracts cannot be canceled without legal (and financial) repercussions. One author describes the inertia of an organization as the "commitment to current strategy" (Huff, Huff & Thomas, 1992). Inertia, from the physical perspective has been defined as "a property of matter by which it remains at rest or in uniform motion in the same straight line unless acted upon by some external force." (Merriam-Webster's Collegiate Dictionary, 1993) This description is consistent with the context within which Huff and colleagues present inertia; they suggest inertia is in opposition to strategic renewal. Inertia in a static organization is essentially maintenance of the status quo. If it were possible for an organization to exist in an environment without change, one would expect a constant stream of activity, yielding a constant level of revenues and expenses. This supports the momentum accounting suggestion that organizations maintain a certain level of activity by merely continuing to operate without change. If the inertia of the organization were zero, then the rate at which income is generated would be constant, and the rate of change in wealth would follow a linear function. An increase or decrease in the rate that income is generated would result in a wealth model that could be simulated as a curvilinear function, should there be a change in an organization's environment.

The smoothness of the wealth function should be indicative of the level of change the organization experiences. Ijiri (1989) indicates that momentum accounting should be built on the momentum of continuing operations. The true wealth of the organization reflects the value of continuing operations and other factors of which the market is aware. The organizational literature also suggests the inertia of an organization is related to the "size" of changes that affect the organization. Small changes yield a continuous, relatively flat inertial response, while major events, such as unexpected catastrophes, may yield a step-level inertial change (Huff, et al., 1992).

The non-static state of organizations is not only acknowledged in organizational research; it is identified as a "strong" force that must be considered when contemplating changes in organizations (Huff et al., 1992).

2.2.4. Physical Science Basis of Momentum Accounting

Momentum accounting derives its roots from the physical sciences. When acknowledging an organization is a moving entity and forces act upon the entity to cause it to move at alternative rates, one can immediately see the possible relationship between momentum accounting and physics. Within physics, kinematics relates to the classification and comparison of motions (Halliday, Resnick & Walker, 1993). To use kinematics as a basis for momentum accounting, one must assume that organizational movement is a continuous function, e.g., for an object (company) to get from point A (wealth in period A) to point B (wealth in period B), it must travel through each point (wealth value) along the way without discontinuity.

To use the rules of physical motion within the framework of momentum accounting, the concepts from accounting must be mapped to the underlying physical concepts. Essential to the rules of motion, the position of the object is the basis for measurement of movement. This movement, or displacement, is described as the change in position. In the framework of momentum accounting, wealth is identified as the first dimension (Ijiri, 1989), or the status of the organization. This is consistent with the traditional view of a start-up company. At inception, a company has no wealth. During the corporation's life, if one excludes capital contributions and dividends, wealth reflects the success or *position* of the organization through a specified period of time. Hence, the mapping of *wealth* is to the physical concept of *position*. When considering the change in position over time, physicists use the first derivative of position, a transformation that yields velocity. Momentum accounting also uses the derivative of position (wealth) to look at the rate of wealth change over time, or the rate of change in the "stock" accounts. Ijiri (1986) calls this concept "income momentum" or simply "momentum"; therefore, the accounting concept of *momentum* is mapped to the physical concept of *velocity*. The second derivative of wealth relates to the impulses that affect an organization. These impulses change the momentum at which the company is earning income. The physical science component that relates to *impulse* is *acceleration*, the application of force to an object that changes velocity.[32] This research builds upon these relationships between organizational concepts and their corresponding physical science components, and it applies the visualizations used to aid in understanding the physical science components to their momentum accounting counterparts.

[32] The consistency of the example is maintained, acceleration is the second derivative of position.

2.3. Visualization System Issues

2.3.1. Tools for Visualization

The area of visual representations has been fueled by the dramatic decreases in the cost/power ratio for hardware and software (Wolff & Yaeger, 1993). Today desktop computers are available with multiple processors, gigabytes of long term storage, megabytes of dynamic memory, and powerful graphic capabilities. This power has allowed the development of large complex programs that are capable of producing a variety of visual representations in relatively short periods of time. Many of these programs have been directed at the end-user of a system, generating more interest in the use of visual representations.[33] Until recently, it was not technically feasible for end users to develop complex visual representations. To draw a graph, one had to write programs to plot each data point, function and axis. In today's environment, the user may only have to specify the data and work through prompts, selecting the details of their representation from lists of options. This "user friendliness" is made possible through the availability of extensive graphics libraries, 4GL programming languages and turn-key visualization software (Brown, Earnshaw, Jern & Vince, 1995).

Today, in addition to the two dimensional graphics that have been traditionally available in presentation packages, software is available that will assist the user in the production of photo-realistic virtual reality simulations. Between these two ends of the spectrum, lie the three-dimensional graphics that may be used to render surfaces and/or volumes.

Many of the current tools have the ability to allow the use of color as a variable, independently or as a redundant representation of another variable. Additionally, it is possible

[33] A review of the all the software packages capable of producing visualizations is far beyond the scope of this dissertation. For a comparison of requirements and features for many of the software packages that are currently available, see Chapter 4 of Brown, Earnshaw, Jern & Vince (1995, pp. 75-124), "Selecting the Software and the Computer."

to prepare visualizations where one may rotate the graphic to view the changes in, and relationships among, the variables from virtually any position. This allows the user to detect important relationships that may occur within the model. To accomplish this "rotation" of an image, one may develop an animation. Animation has been defined as the "rapid display of a sequence of images" (Wolff & Yaeger, 1993). One goal of animation is a smooth transition through the sequence of images. The human eye and brain can process two sequential images and interpret them as continuous in approximately one-tenth of one second, or ten frames per second (Wolff & Yaeger, 1993). At an image display rate of less than ten frames per second, one would perceive a jerking motion rather than a smooth motion. At the other end of the spectrum, videos are generally recorded at thirty frames per second. "More than 30 frames per second really doesn't have much effect on the viewer" (Wolff & Yaeger, 1993, p. 46).

When considering a computer animation, one must consider the equipment on which the animation is processed and viewed. When using animation as an independent variable, the length of time it takes to view the animation may vary significantly between computers. The complexity of the visualization (i.e., the size of the file in which it is contained) combined with bottlenecks (i.e., low transfer rates) on the equipment on which it is viewed, may reduce the actual frame count per second (Wolff & Yaeger, 1993). From the hardware perspective on a stand-alone system, one can address this issue through increasing the transfer rate for storage devices, or the increase in RAM to allow for RAM storage and buffering of the data. Over networks, the problem has been addressed in some packages through the use of data streaming. Data streaming allows the display of a visualization to begin prior to the receipt of an entire file from across a network. This is an extremely important issue with regard to implementation of animation across the Internet, where there are a variety of transfer times, based on factors not controllable by the animation developer. When developing a visual application, one must consider the equipment that may be in use by relevant users. This may lead to increased complication (or require simplification) of research projects and production systems.

To date, much of the literature published related to visualizations, from the information systems viewpoint, is descriptive in nature.[34] The focus from the research perspective parallels the cognitive psychology and financial literature previously discussed, concentrating on the ability of visualizations to combine and present data to enhance the decision making process. With the availability of computers and software today, the capabilities of visualizations have been increased, but likewise so have the complexities that must be considered in a valid representation.[35]

2.3.2. Color in Business Visualizations

The use of color was introduced to the "graphical decisions" business literature through a study that used an experimental decision model to optimize profit (Benbasat & Dexter, 1985).[36] Their study compared results for subjects that used one-color versus multi-color graphs to make a promotional budgeting decision that resulted in changes in profits. The graphs that were tested, displayed the functional relationship between promotion/profit for multiple territories. One factor that they controlled was time, with one group of subjects having five minutes to make the decision, and another group having fifteen minutes. They found that by simply using multiple colors to implement the graphs, the decisions were better[37] for the group having only five minutes to complete the task. It should be noted that their use of color was redundant; all of the information was available without the use of color. Their

[34] See Brown et al., (1995) for a history of graphics and scientific visualization.

[35] Grinstein and Levkowitz (1995) contain a series of papers addressing specific topics relating to perception issues.

[36] Benbasat et al. (1985, 1986, 1986a, 1986b) studied color in decisions under a variety of assumptions.

[37] "Better" is operationally defined as a higher profit in decision case used.

results are consistent with Hoadley's (1994) research regarding color supplanting other information. In this context, supplanting refers to the ability of color to supersede the processes that would otherwise be required for a decision to be made. The supplanting functions used by Hoadley's subjects included the following: 1) discriminating, 2) organizing, 3) disembedding, and 4) quantity visualization (Hoadley, 1994, p. 94). Because Benbasat and Dexter's experiment used redundant data and differences were only found for the lower time group, one cannot conclude that color alone made the difference.

There have been several other studies in management information systems literature relating to the effect of color. Hoadley (1990, p. 121) summarizes the results as follows:

"
- color improves performance in a recall task
- color improves performance in a search-and-locate task
- color improves performance in a retention task
- color improves comprehension of instructional materials
- color improves performance in a decision judgment task."

This research used color with visualizations developed to examine decisions regarding predictions. Lohse (1993) confirmed the previous research that color aids decision making when using graphs, but equally important suggested that the decision usefulness of a visualization depends on the task being investigated.[38] Much of the previous business research focused on the existence of color, rather than the importance of color(s) used in the representations. Tufte (1990, 81) summarizes his view of the complexity of the color selection process for visual displays by stating:

[38] For an analysis of the results of graph versus table literature from the perspective of the problem fitting the presentation format, see Vessey (1991).

> "The often scant benefits derived from coloring data indicate that even putting a good color in a good place is a complex matter. Indeed, so difficult and subtle that avoiding catastrophe becomes the first principle in bringing color to information: *Above all, do no harm*."

One does not generally think of the introduction of color as potentially harmful, but any part of a visual representation that detracts from the data may be detrimental to understanding or decision-making.[39] This study includes the use of color to convey the strength of impulses that change momentum, thereby, changing wealth. Because the impulses are potentially more significant when at the positive or negative extreme, a double ended color scale is used to provide more distinction and thereby help the decision-maker understand the data (Rheingans & Landreth, 1995).

2.3.3. Image Rotation in Visualizations

Psychological and human computer interaction research has investigated the perception of visual representations and storage of images.[40] Intuitively, one can reason that rotation of a 3D object provides a better understanding of the interaction among the variables. Pani (1993) examined the comprehension of rotational motions and concluded that when rotations are about an axis (rather than oblique), the rotation is better understood by the subject.[41] This is consistent with Shepard and Metzler's (1971) work regarding the increase in time for subjects to comprehend similar 3D objects as the angles at which they are presented increase.

[39] Tufte (1990, 80-95) provides an excellent group of guidelines and examples to enhance the use of color in a variety of visual representations. Rheingans and Landreth (1995) also give several details effective use of color in visualizations.

[40] For a concise overview of mental imagery, see Kosslyn, Behrmann and Jeannerod (1995).

[41] Pani's representations depict items from a physical domain, rather than abstract concepts.

Wickens, Merwin and Lin's (1994) investigation of the visualization of scientific data includes an analysis of motion and rotation in 3D displays. They test subject's extraction and retention of data from 2D and 3D visual representations. They report superior retention for 3D representations over 2D representations. Differences due to the ability to rotate the surfaces of 3D graphics were not found.

One group of subjects in this dissertation used a 3D graphic that can be rotated, with the rotation being permitted concurrently around the x-axis and the y-axis. This rotation is controlled by the subject to allow views that enhance their understanding of the image.

2.4. Experimental Visualizations and Hypotheses

2.4.1. Development of Visualizations

Visualizations provide a method of understanding complex information by accumulating, grouping, and displaying data in a manner that may be understood more effectively than viewing the details of the data. A basic description of an information visualization is a report format. One of the interesting features of momentum accounting is the functional nature of the information. The time series nature of the momentum accounting functions provides an excellent domain that may be represented within a visualization framework. The basic purpose of this study is to develop and test visualizations that may be used to effectively represent the information provided by a momentum accounting system.

For this dissertation, several representations have been developed to express the information provided by momentum accounting. The first representation (hereafter R1; see Exhibit 1) is a two-dimensional line graph, demonstrating the functions of wealth, momentum and impulse independently. This is a combination of the typical representation based on the physics concepts (Brown, et al., 1995, p. 57; Halliday, Resnick & Walker, 1993, p. 21) that have been shown to underlie momentum accounting concepts. This graph displays the relationships between the data in a close proximity. A complicating feature of this representation is the multiple y-axes requirement and the y-axes scales, due to the unit of measurement differences between the functions. Because the experimental predictions are based on wealth, R1 uses wealth for the y-axis. The scale issue is addressed by the multiplication of the underlying momentum and impulse functions by a constant to allow similar relative values for each of the underlying functions. It should be noted that the individual representations of the line graphs included in R1 were not tested because they do not represent a different form than R1; they merely are located at varying distances from each other, rather than plotted along the same axis as demonstrated in R1.[42] Representations 2 and 3 (R2/R3; Exhibit 2) are three dimensional time series graphs with time on the x-axis, wealth on the y-axis and momentum on the z-axis. Color is applied to the 3D surface to represent impulse, creating a fourth dimension. R2 is presented as static and R3 is a rotated visualization of R2[43] to allow the user a better understanding of the data presented. Wickens, Merwin and Lin (1994) have tested rotations of images, but their study focused on extracting information from visualizations rather than the predictive use of the information.

2.4.2. Hypotheses

Numerous studies have shown that graphical formats may generate "better" decisions than those based on traditional accounting formats (Anderson & Kaplan, 1992; Anderson & Reckers, 1992; MacKay & Villarreal, 1987; Stock & Watson, 1984). For functional information, such as that derived from a system of momentum accounting, visualizations can be used as a tool to help understand the data. From the psychological perspective,

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[42] Wickens and Carswell (1995, 474) describe the proximity compatibility principle (PCP) and note: if the distance is increased between multiple sources of information required for a decision making task, the task integration requirements are increased.

[43] For a "static" representation of R3, see R2 in Exhibit 2.

multivariate representations may exist that produce varying levels of decision effectiveness based on the perception and interpretation of data (McCormick, DeFanti & Brown, 1987). This line of reasoning suggests that when visualizing momentum accounting information based on the representation used, there will be a difference in the accuracy of decisions and the time required to understand the data and make a decision. The first hypothesis (stated in the null) is as follows:

$H1_0$: There is no difference in decision accuracy due to differences in visual representations.

The rejection of this hypothesis indicates that there is a difference in the dependent variable relative to the representation presented. The alternative, $H1_a$, suggests a difference exists. In this study, three different visual representations were used (R1-R3). Wickens, Merwin and Lin (1994) indicate that extraction and retention of data is superior for 3D images over 2D images. Cooper (1990) indicates that subjects prefer 3D representations to 2D representations. Therefore, it was expected that R1, the two-dimensional representation, would be associated with the lowest subject performance in the experiment. Pani (1993) reports that the angle of rotation affects the comprehension of an object that is presented within a 3D representation. This study, combined with the reasoning that the comprehension of variable interaction will increase, when that interaction can be viewed from various positions, leads to the expectation that R3, the three-dimensional rotatable image, should be associated with the highest subject performance.

Decision accuracy may be related to variables other than the method of data representation. Betts (1909), Kosslyn, Behrmann and Jeannerod (1995), and Marks (1973) all find that visual skills are important to interpreting data and decision-making. The second hypothesis, stated in the null form, relates to the subjects' accuracy relative to their visual skills.

$H2_0$: There will be no difference in decision accuracy due to individual visualization capabilities.

The alternative to H2 would indicate that because each display contains graphical information, subjects with higher visualization acuity should perform better than those subjects with lower visualization skills. This is consistent with the psychology literature that suggests that visual imagery plays an important role in memory (Marks, 1973) and reasoning abilities (Kosslyn, Behrmann & Jeannerod, 1995).

In addition to accuracy, the time to make a decision is important to the decision process. Benbasat and Dexter (1986) found that when time constraints exist, decisions can be improved based on the presentation format. The third hypothesis, stated below in the null form, is used to investigate the effect of data representation on the time required by subjects to make decisions.

$H3_0$: There will be no difference in time taken to make decisions due to different visual representations.

Benbasat and Dexter (1985) suggested that when using multiple forms of information representation to solve problems, differences in time to solve problems may exist. As the dimensionality of the representation increases, approaching the dimensionality of the data, the task of understanding the representation should be less intensive, allowing faster decisions. An alternative to H3 indicates that the time required to solve the experimental problem varies based on the representation used. Cooper (1990) reports that when presented with a 2D representation of a 3D problem, subjects mentally create a 3D representation. This suggests that subjects using R1 should require a longer time period to answer the experimental questions (their time includes a mental conversion to a 3D representation). Subjects using R3 should have the lowest decision-making times, because the information is presented in a format that shows the relationships among the data.

The hypotheses represent an investigation of the differences among proposed representations of momentum accounting information. They also consider the visual acuity factor that may be important within the decision making environment. Each hypothesis was investigated and tested within the current study.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

> "Not a great many substantive problems, however, are exclusively two-dimensional. Indeed, the world is generally multivariate. For centuries, the profound, central issue in depicting information has been how to represent three or more dimensions of data on the two-dimensional display surfaces of walls, stone, canvas, paper, and, recently, computer screens."
>
> \- Edward Tufte[44]

3.1. Experimental Design/Independent Variables

For this dissertation, the investigator used a laboratory experiment to examine certain data representations on which predictions may be based. These representations were hypothesized to impact the understanding and interpretation of momentum accounting data, measured through accuracy of predictions of wealth. The experiment was executed in a computer laboratory environment with the subjects being placed in a booth with a desktop computer. The laboratory computers contained the experimental programs including instructions, demographic questions, and visualizations on which participants were asked to make predictions. A between subjects factorial design was used to test the hypotheses. The independent variables include the type of visualization received by each subject (manipulated variable) and the subject's level of visual perception (measured variable).

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[44] From Tufte (1997,p. 17).

3.1.1. Experimental Visualizations

There were three types of visualizations used in the experiment, with each subject being exposed to only one of the three types. The first type of visualization (R1 - Exhibit 1) was a 2-dimensional line graph. The x-axes, measured in months, ranged from one through one hundred-twenty for each of the representations. The y-axes range, measured in dollars, varied based on the individual companies used for data. Each graph contained three lines, with each line representing a function for either the wealth, momentum or impulse of a company.[45] The lines were displayed to show the functions for months seven through one hundred for a specific company. Because of the nature of the functions (the derivative relationships among wealth, momentum and impulse), it was necessary to multiply momentum and impulse by constants to allow all three functions to be displayed on the same graph in a meaningful manner.[46] Each line on the visualization was displayed in a unique color.

The second visualization was developed to combine the three 2-dimensional lines from the first representation into one 3-dimensional representation (R2 - Exhibit 2). This was accomplished by creating a 3-dimensional function by adding a z-component and color to a 2-dimensional function. In the new representation, time (month) was maintained as the x-axis and wealth as the y-axis. Momentum was added as the z-axis[47] and the color of the line at any

[45] The development of these functions, used in development of the representations, is discussed in Section 3.1.1.a.

[46] Because of the derivative relationships, when plotted on the same scale as wealth, the momentum and impulse functions appeared flat, when actually there was substantial variation within the functions when plotted on smaller scales. The multiplication of a function by a constant does not change the shape of that function, but simply changes the scale of the plot.

[47] For a general model of graphing three functions in a 3D space, see Kriz (1995).

point on the line represented the impulse for a company at that point in time.[48] A line was plotted based on the values for the functions for the same time range used in the 2-dimensional representations. This representation was displayed from a position of 30 degrees above the xz plane and 35 degrees to the left of the yz plane.[49]

The third representation (R3 - Exhibit 2) was created to look identical to the R2 representation. The only difference was the ability of the subjects' to rotate the image to view the data relationships from different perspectives. The vertical rotation was allowed for 360 degrees (completely around the y-axis) and the horizontal rotation was allowed for the 180 degrees (the top half of the sphere divided by the plane xz).[50]

<u>3.1.1.a. Function Determination/Company Selection</u>

The wealth function for a specific company was generated based on historical data for the company's monthly market equity (month-end stock prices times the number of shares outstanding at the end of the month). The derivative of the generated wealth function was taken (with respect to time) yielding the momentum curve. A second derivative was taken to produce the function of impulses. These three functions were used for visualizations and predictive purposes.

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[48] The use of a color overlay to add information to a graph is common when creating visualizations. See Wolff and Yaeger, Chapter 4 for several examples.

[49] This angle was selected through observations of other static 3-dimensional representations and discussions with several individuals. The individuals were allowed to rotate a graph and asked what angle they would choose to display the graph for decision making, if the image could not be rotated. With no exceptions, the individuals choose the approximate angle that was used in this research.

[50] A graphics expert suggested that subjects would receive no additional benefit from the bottom half of the sphere (Lockhart, 1997).

Compustat PC Plus[51] was used to select the companies used in the study. Companies were eliminated from the Compustat selection that did not have market values for months -15 through -190 (months relative to the current month -- August 1996). This exclusion of companies eliminated those companies that were not in business at either end of the points in time. This was necessary to ensure they were in business during the entire period for which the wealth functions were to be generated. From these criteria, 585 companies were selected. One assumption stated as a requirement for the study was the exclusion of companies that pay dividends.[52] The data regarding dividend history from these companies were exported to a Microsoft Excel[53] spreadsheet where they were visually inspected; any company that paid dividends during the periods under observation eliminated, reducing the total to 188 companies. These companies were ranked according to total market value at the end of 1995; the group was then divided into thirds. Two companies were selected from each of the high and low thirds based on their relative rate of wealth growth during the period and total wealth. These companies are identified as large company/high growth (LH), large company/low growth (LL), small company/high growth (SH), and small company/low growth (SL). Two other companies were identified as having "interesting" patterns[54] and were selected to be used as training cases for the experiment.

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[51] Version 5.2.1, copyright 1996, Standard & Poor's Compustat, a Division of The McGraw-Hill Companies.

[52] See Section 2.2.2.a.

[53] Microsoft Corporation, Redmond, Washington.

[54] I.e., a variety of directional moves relative to wealth, momentum and impulse.

After selection of the companies, monthly market value (wealth) data for 133 months were accumulated into a file and imported into a SAS[55] data file. The Interactive Data Analysis section of the SAS program was used to visually match a "nth" degree polynomial to a plot of the data for each company. The visual match consisted of the investigator's increasing the polynomial degree until a proper curve fit was accomplished. The match was considered to be an acceptable fit of the function when the graph displayed the major turns of the function and the R-values for the polynomial generally were in the range of .7 to .9. When the degree of the desired polynomial was determined, that information was used to generate a model equation with Mathematica.[56] [57]

Subsequent to the generation of the model functions and their first and second derivatives[58], the functions were input into a Microsoft Excel spreadsheet. Excel was used to generate data points for graphing. The data points were generated for months 7 - 100, for wealth momentum and impulse. Months 1-6 and 121-133 were eliminated, because of statistical issues that may exist in rounding endpoints when generating equations from data points. Months 101 - 120 were not used for graphing because they included the prediction periods for the tasks. The data sets for each company were saved into separate comma

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[55] Version 6.11, copyright 1989-1996, SAS Institute Inc., SAS Campus Drive, Cary, North Carolina USA 27513.

[56] Version 3.0, copyright 1988-1996, Wolfram Research, Inc., 100 Trade Center Drive, Champaign, IL 61820 USA.

[57] Mathematica, rather than SAS, was used to generate the equations due to rounding of SAS reports, and the ability of Mathematica to generate the derivatives that were required to produce the momentum and impulse functions.

[58] Exhibit 3 includes the polynomials, derivatives and graphs generated using Mathematica.

delimited ASCII files. These files were imported into PV-Wave Advantage for Windows[59] to develop the images used in the experiment.

3.1.1.b. Visual Image Development

PV-Wave was used to produce bitmap images of the data for each individual company and representation. For each company, three representations were developed, R1, R2, and R3. For the R1 and R2 representations, only one image each per company was required. The PV-Wave commands used to generate these images are included in Exhibits 3 and 4, respectively. Because of the nature of R3 (an image that can be rotated), the complexity level of the image generation was higher than for the other two visualization representations. R3 required the generation of horizontal bands of images, each containing 72 images.[60] Nineteen horizontal bands were created[61] using the program in Exhibit 4. Each company required a total of 1368 images to generate R3. After generation of the individual images for R3, Adobe Premier[62] was used to link the images together and create a QuickTime[63] movie. The movie was converted to a linkable object that could be rotated, by QuickTimeVR[64]. The rotatable object was used as R3. This process of image generation and object creation was repeated for each experimental company and for both of the training companies. The images were linked

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[59] Version 6.02, copyright 1996, Visual Numerics, Inc.

[60] Seventy-two (72) images per band equate to one band for every five degrees of vertical movement around the z-axis (360 degrees divided by 5 degrees).

[61] Nineteen (19) horizontal bands were required because the representations included only the top half of the sphere bisected by the x-z axis (90 degrees divided by 5 degree intervals yields 18 bands; one more band was required because both the top and bottom of the hemisphere, at 0 and 90 degrees were included).

[62] Version 4.2, available from Adobe Systems Inc., San Jose, CA.

[63] Version 2.5, available from Apple Computer Inc., Cupertino, CA.

[64] Version 2.0, available from Apple Computer Inc., Cupertino, CA.

together with the textual and feedback content of the experiment, with Macromedia Director.[65]

The textual information is contained in Exhibits 12-12E, including background information on momentum accounting (Exhibit 12), the introductions for the training task (Exhibit 12A) and experimental task (Exhibit 12B), and specific treatment specific information (Exhibits 12C, 12D and 12E).

3.1.2. Visual Perception

The second independent variable is visual acuity, measured by the VVIQ form (Exhibit 5). The VVIQ consists of sixteen statements of physical objects or visual events. Each subject responded to the sixteen statements on the form with an integer ranging from one through five relating to how vivid the image was to them (1=no image, 2=vague and dim, 3=moderately clear and vivid, 4=clear and reasonably vivid and 5=perfectly clear and vivid as normal vision.) The scores were an average of the responses (total of numeric responses divided by 16 statements), yielding a theoretical range of one through five. Visual perception is a continuous variable based on each subject's score on the VVIQ form.

3.2. Dependent Variables

The data collected from each case include numeric values of wealth predicted for a future period by each subject. For each company, the subjects predicted wealth for one, ten and twenty month(s) beyond the graph values. The dependent variable, predicted wealth accuracy, was measured for each subject for each prediction period, by taking the difference

[65] Version 5.0, Available from Macromedia, Inc., San Francisco, CA.

between the subject's predicted wealth (S) subtracted from model predicted wealth (M) provides the wealth accuracy (WA) value.

$$WA = M - S \qquad (5)$$

The model predicted values were obtained from the wealth functions determined above for the months of 101, 110 and 120.

A second dependent variable examined consists of the time it takes a subject to process a visualization and make a prediction. The variable is measured through the use of the computer's internal clock, measuring in seconds the prediction time since the previous response. This should be a reasonable measure because the acceptance of an answer automatically causes the program to display the next question and/or the information regarding the next company. There was no fixed time limit imposed on the subjects[66] although the reward system (Exhibit 6) was structured to provide incentives for speed if it is not obtained at the expense of accuracy. Because of the method of collecting the times, each prediction occurrence generated an occurrence of the time variable.

3.3. Other Measures and Collected Data

In addition to the dependent and independent variables required for the statistical analysis of this research, several other questions were included. Demographic questions (Exhibit 7) were included to ensure the random assignment to groups. Items requested

[66] Unofficially, there was a 90-minute limit on the experiment time due to scheduling of appointments, but no subjects took the entire allotted time. The 90-minute appointment schedule was set to give enough time to complete the experiment. It was based on the range of 25 to 60-minute times for graduate students assisting with the pilot test.

included data relating to age, gender, grade point average, work experience, computer experience, and experience with graphics. In addition to the demographic questions, several post-task questions (Exhibit 8) relating to the experiment and the subjects' use of the information were asked. In addition to the questions, the investigator made audio recordings of the subjects "thinking aloud" during their decision-making process. The data from this recording along with the post-task and demographic questions will be examined in future research for the purpose of obtaining additional information relative to visualizations, momentum accounting and decision-making.

3.4. Statistical Analysis

The two independent variables, presentation method (based on the three representations), and VVIQ scores were analyzed with respect to the predicted income accuracy. The analysis consists of nonparametric procedures to establish differences between treatments for the independent variables. H1 was tested by examining the presentation method variable without respect to VVIQ score variable, while the H2 test ignored the presentation method and tests only for VVIQ score differences. H3 was used to examine the differences in time to complete the case instrument, based on the type of visualization used.

3.5. Subject Selection

Subjects for this research were selected from senior and graduate business school students at a major, eastern, state university. These students were used because they are close to entering the job market in positions that should require basic decision making. They are a relatively homogenous group with basic training in financial decision-making. They have had exposure to financial statement representations. They should not be biased for or against the "new" concepts presented by momentum accounting. The usable sample consisted of 124 subjects[67]; this allowed for the assignment of approximately forty students to each of the case groups.

Subjects were recruited from two courses at the university. One course was a senior level auditing course with class members being exclusively accounting majors. The second course was an upper-level managerial accounting course with members being primarily of senior status and business school, non-accounting majors.[68] There were two sections of each course. It should be noted that other courses were available to the investigator, but the interesting stratification of majors within upper level college students provided the basis for the choice of these subjects; this interest in the stratification existed because of the assumed differences in backgrounds of the subjects. Although none of the subjects had knowledge of momentum accounting, the auditing subjects had a stronger background in general accounting theories and practices than did those in the managerial course. A managerial accounting course's subjects' training is assumed to be more in the use of accounting information to make decisions, rather than the mechanics of developing financial information, which was assumed to be the background of the auditing students.

For the actual recruitment of subjects, the investigator presented to both sections of each class, a brief (approximately five minutes) overview of the research topic, dates and

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[67] The actual number of participants was 130; 6 subjects were eliminated due to program failure or not completing the experiment. The six subjects were distributed across the three representations.

compensation[69] for the experiment and passed around sheets with time schedules. Students signed up for their choice of times. The sign-up sheet listed each participant's name, e-mail/phone number, and instructor. No students from either of these courses were kept from selecting a time, although the sample size was increased slightly due to the high percentage of participation. Ultimately, the subjects participating in the study included 76 students from the auditing course and 54 students from the managerial accounting course.

3.6. Experimental Procedures

A total of 124 of the 130 subjects participated in the experiment and provided useable results over a two-week period. The day prior to each participant's scheduled time-slot, the subject was called or e-mailed a reminder of the scheduled appointment. Each subject was instructed to arrive at the investigator's office at his or her selected time. Time-slots were scheduled for ninety minutes each. Three subjects were scheduled for each time-slot. Upon the participant's arrival, they were given a copy of the "Informed Consent" form (Exhibit 9) to read.[70] The investigator verbally highlighted the risk (none), confidentiality (no person external to the experiment would be able to associate an individual's results with that individual), compensation (hourly rate, course credit, and bonus possibilities), and participants' responsibilities (answer questions accurately and quickly, maintain the

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[68] The students in the managerial course were primarily business management and finance majors.

[69] Details of the compensation plan are included in Section 3.6.3.

[70] The university where the research was performed requires the form; it includes information such as the risks involved in the study, confidentiality, and compensation for the subjects, and the responsibilities of investigator and subjects.

confidentiality of the experiment). Each subject signed and returned a copy of the form. Each subject was also given a copy of the form to keep for his or her future use.

After signing the Informed Consent form, the subjects were read instructions (Exhibit 10) about the experiment. The intent of reading these instructions was to give each subject an idea of what to expect regarding the physical execution of the experiment, limiting surprises and distractions for the subjects during the time each was in the lab working on the experiment. Participants were reminded (also disclosed in the informed consent form) that the experiment would be recorded (an audio recording) and requested to “think aloud” during their decision making process. The instructions also described the structure of the experiment. The training task would require them to predict seven values for two companies; they would receive the correct answer after each prediction. The actual experimental task would operate the same as the training task, with the exception that no correct answers would be given. They were then informed of the post task questions, the VVIQ questions and the demographic questions. To complete the experiment, they were instructed to save their answers (click on save). After completion of the experiment, participants were asked to return to the investigator's office to sign-out (for their course credit) and receive their cash compensation. Based on pilot testing of the experiment, a few other issues also were addressed in the verbal instructions. These issues included informing participants that they could predict outside the range of the axes displayed in their visualization, and the required cursor positioning when typing their predictions. They were also instructed to carefully read each question, due to the similarity of questions (often different by only one digit (numerically) or word. Finally, they were reminded to read all instructions and to think aloud.

Upon completing the oral instructions and answering any questions from the subjects, the investigator escorted the subjects to the laboratory where the experiment was conducted. Each subject was shown his or her designated booth. The investigator activated the audio recorder and closed the door to the booth.

At the completion of the experiment each subject returned to the investigator's office where they signed-out and were compensated. A separate sign-out sheet was provided for each section of each course. Subjects completed the process in a time frame of twenty-five to eighty minutes. Generally, it took approximately fifty minutes to complete all of the procedures related to the experiment. The subjects were compensated for a one-hour minimum. Those taking more than one hour were compensated for the time in excess of one hour in one-tenth hour increments. Each subject signed a receipt confirming the receipt of his or her cash compensation.

3.6.1. Random Assignment of Subjects

Based on the desired sample size of one hundred-twenty subjects, requiring twenty subjects in cells for each of two significantly different orders of three representations, the investigator developed an "experimental control" spreadsheet with 120 rows; twenty of each were labeled with the numbers 1 through 6, signifying the twenty subjects desired for groups 1 through 6. The experimental representations R1, R2 and R3 used groups 1/2, 3/4, and 5/6 respectively. Each row of the spreadsheet was then assigned a random number, using the random number function in the spreadsheet. The spreadsheet rows were then sorted by the random numbers, yielding a random order for the group assignment. Each row, for each group, was then assigned a consecutive number (1 to 20) to be used as a designation for the subjects within a group (for example 4-14 was the fourteenth subject in group 4). As each subject arrived for the experiment, they were assigned to the next group on the list, yielding a random assignment of subjects to groups.

To facilitate the experiment, 120 diskettes (3.5 inch), 120 audio cassettes (90 minutes), and 120 three by five index cards (for control purposes) with the group/observation numbers were prepared in advance of the experiment.

In preparation for the study, the laboratory was set-up for three administrations of the experiment. The laboratory consisted of a rectangular area with three booths on each side of a hallway. The booths had floor to ceiling walls, one or two tinted windows and one door. Because the booths were not sound-proof, only three booths were used concurrently; the end booths on one side of the hallway and the middle booth on the other side of the hallway. This setup left adequate space between the subjects to prevent interference between participants in the same time-slots. To allow for control of differences due to the physical location or specific computers used by participants, the participants were assigned randomly to the booths/experiment computers. This randomization was accomplished by the calculation of three random numbers (using Excel's random number function) for each time-slot, and then assigning group rows (observation numbers) to machines based on the order of these random numbers. The machine/booth number was added to the above described index cards.

The laboratory booths each contained a Gateway 2000 P-75 computer (75 MHz Pentium processor) with 16 megabytes of random access memory and approximately 100 megabytes of free hard drive space. The operating system used was Microsoft Windows 95.

No other applications other than the experiment program were active. Each machine had a two-button mouse and a 15-inch color VGA monitor. The monitor resolution was set to 800X600.

Prior to the arrival of subjects in the laboratory booths, the investigator started the appropriate experimental programs that related to groups assigned to the next subject arrivals. The investigator also inserted into the designated computer and audio recorder, a diskette to record their responses and a cassette to record their "thought process," respectively. This procedure allowed the subjects to begin working upon their arrival, without distraction of the room preparation.

The investigator monitored the responses as they were completed and determined that six were not suitable for inclusion in the results. To complete the desired sample a procedure similar to the above group randomization was completed. The group numbers for the unusable observations were listed in rows of an Excel spreadsheet, random numbers were assigned to each row and the rows sorted by the random numbers, yielding a random order. After the first 120 subjects were processed, the next six were assigned to groups in this order. These subjects (121-126) replaced the unusable observations. After the replacement of the unusable observations, there were four subjects remaining on the schedule to participate in the study. To ensure an equal chance of assignment to a group, the group numbers one through six were listed in rows of an Excel spreadsheet, random numbers were assigned to each row and the rows sorted by the random numbers, yielding a random order. To complete the total randomization of subjects' process, the remaining subjects were assigned to the randomized groups as they arrived.

3.6.2. The Task

Prior to being taken to the lab, participants received oral instructions regarding the experimental procedures. When a subject entered an experimental booth, the program that guided the experiment was displaying the initial instructions. These instructions described the experiment and the tool the subject used to visualize the data set. Two sample problems gave them practice and feedback on making predictions using the tool. After the practice problems, all participants were presented with visualizations of momentum accounting information for four companies and asked to make predictions for future periods for wealth (three predictions), momentum (three predictions) and impulse (1 prediction). Exhibit 11 includes the questions used for soliciting the predictions from each subject.

The prediction tasks included a case in which each subject was asked to look at a visual representation of historical data for specific companies. The case was developed considering the work of DeSanctis and Jarvenpaa (1989). Their study investigated the predictions involving accounting data for forecasting purposes. Their results were based on the outcomes varying for graphical or numerical formats of the information. The prediction required of the subjects in the current study included recognizing trends of wealth (R1-R3) based on the visualizations presented. Although the topic of this experiment is not traditional accounting information, it deals with and requires recognizing the trend of wealth, a traditional accounting concept. The experiment was based on visualizations of the non-traditional accounting information.

Because some subjects did not have a thorough understanding of accounting terms, the relevant terms applicable to the traditional and non-traditional information were described within the instrument. Subjects' predictions of wealth were for three points in time following the last period for which information was presented in each visualization. Subjects predicted to the nearest dollar, what they believed the wealth would be in that period. There was no prescribed time limitation for the predictions, although each subject was scheduled for a 90 minute session, yielding a practical limitation. Subjects were instructed to answer to the best of their ability and as quickly as possible, but not to the detriment of accuracy. Variation in subjects' accuracy due to time restrictions is explained by at least one of the independent variables.

After completion of the case, subjects answered post-task questions (Exhibit 8). Next, the Vividness of Visual Imagery Questionnaire (VVIQ) was administered, and finally demographic questions (Exhibit 7) were answered. VVIQ information was collected and included in the statistical analysis relating to H2, to determine effects based on individual ability differences. The VVIQ was administered and the other demographic data were collected at the end of the experiment to limit any experimental bias relating to their content.

The predictive results and additional information were collected on the diskette along with the times each subject took to answer each question in the training session and actual case. The data was accumulated from each diskette and analyzed.

3.6.3. Reward System

A reward system was developed to attract and compensate the participants (Exhibit 6). The compensation package included guaranteed cash and extra credit in the course from which the subject was recruited. The guaranteed cash consisted of six dollars per hour, paid in one-tenth hour increments.[71] Additionally, for their participation in the research, subjects received a course-credit bonus of one percent of the total possible points available in the course from which they were recruited. Because no subjects were members of both classes, the grade compensation was equal for all subjects. The credit and hourly rate were effectively an appearance fee, included to facilitate the recruitment of subjects and establish credibility of the experiment (Davis & Holt, 1993, 26).

In addition to the guaranteed segments of the reward system, each subject was entered into a "bonus pool" or lottery with the chance of winning additional cash. Three "pools" were established, one for each type of representation (R1, R2 and R3). Each subject received one entry in the lottery based on simply participating in the experiment. Additional entries were awarded, based on the accuracy and speed. Subjects in the top quartile, based on accuracy[72], were awarded three additional entries in the lottery. Those in the second quartile, two additional entries, and one additional entry for those in the third quartile. In addition to the accuracy bonus entries, subjects in the top two accuracy quartiles were given speed-bonus

[71] Operationally, each subject received pay for a minimum of one hour.

[72] Accuracy was determined by ranking the accuracy for each prediction for each subject within a representation group (1 = highest rank). The ranks for all predictions were summed and the subject with the lowest total composite score was the highest ranked subject.

entries if they were in the top two speed quartiles.[73] The speed bonus consisted of 4 additional entries if the subject was in the top speed and top two accuracy quartiles and three additional entries if the subject was in the second speed quartile and in the top two accuracy quartiles. It should be noted that speed was not a factor in bonus entry determination if accuracy was not in the upper two quartiles. The compensation was structured in this manner to discourage subjects from sacrificing accuracy for speed.

Three bonus pools were used because a difference in accuracy based on the representation used was hypothesized; it would be an unfair disadvantage to subjects if, because of their random assignment to groups, a subject's accuracy was decreased, moving them to a lower accuracy quartile. From each bonus pool, two "winners" were selected. The first received $75 and the second $25. To select the winners, a Microsoft Excel spreadsheet was developed with a row for each entry (ranging from one to eight entries per subject). Each row was assigned a random number. The subject that was identified with the row with the lowest random number received the first prize and the highest random number received the second prize. Prizes were awarded approximately two weeks after the experiment was completed. The use of a bonus pool established a portion of the subject's total compensation as performance pay; subjects performing accurately and quickly had more chances in the lottery, yielding a higher payoff value. The relationship of task performance and payoff value is important in the design of a compensation package (Davis & Holt, 1993). Evidence of the

[73] Speed quartiles were determined by ranking the speed for each prediction for each subject within a representation group (1 = fastest speed). The ranks for all predictions were summed and the subject with the lowest total speed composite was the highest ranked subject.

effectiveness of the package includes the rate of subject participation (94%).[74] Supporting this belief, several subjects made unsolicited positive comments about the component of the compensation that provided incentive for them to participate (some cash, some course credit and some the bonus possibility).

[74] 94% of subjects signing up for the experiment actually participated.

CHAPTER 4

EXPERIMENTAL ANALYSIS AND RESULTS

4.1. Strategy for Statistical Analysis

To determine the analytical procedures that were appropriate to use when examining the experimental data, certain diagnostic statistics were calculated and assessed. Based on this assessment, nonparametric procedures were used to analyze the data and test the hypotheses proposed in Chapter 2. This chapter includes the diagnostic statistics, a discussion regarding why nonparametric procedures were used, the results of the nonparametric procedures, and the tests of hypotheses.

4.2. Description of the Sample Data

The experiment, described in Chapter 3, yielded twelve wealth predictions (three for each of four companies), the associated prediction times, and VVIQ scores for 124 subjects. Demographic data based on the three samples, using the three experimental representations, are included in Table 4.1. The representation types included are 2-Dimensional graph (R1 or 2D), the 3-Dimensional static graph (R2 or 3D Static) and the 3-Dimensional rotatable graph (R3 or 3D Rotate).

TABLE 4.1 – DEMOGRAPHIC DATA

	R1	R2	R3	Total
Sex:				
Female	17	19	18	54
Male	24	22	24	70
Major:				
Accounting	19	29	23	71
Finance	12	4	6	22
Management	7	8	12	27
Other	3	0	1	4
Computer Experience:				
Mean years	5.9	6.0	5.4	5.7
Work Experience:				
Mean years	4.8	3.6	2.7	4.5

The raw prediction data were processed to determine the accuracy of each wealth prediction. Accuracy was measured as the absolute value of the difference between the subject-predicted value and the model-predicted value was used. The model value was determined by substituting the desired prediction period into the formula used to graph the wealth function. The model value was used in this calculation, because it represents the "best" information that was available to the subjects when making their decisions. This determination of this model value is based on Brunswik's lens model.[75] This model suggests that a subject, provided a model representation of data, cannot predict better than the model; the subjects' prediction accuracy is based on the imperfect cues provided by a model that cannot take into account all environmental factors that affect a decision (Ashton, 1982, p. 15).

[75] For a detailed description of Brunswik's Lens model and the model's application to accounting predictions, see Ashton (1974).

Using a value other than the model-generated value to measure accuracy would have introduced an environmental error factor into the experiment.

Several procedures were initially used to examine these prediction accuracy data and the remainder of the raw data. Table 4.2 includes several descriptive statistics for the accuracy data by representation type, the data required to test the first hypothesis.

TABLE 4.2 DESCRIPTIVE STATISTICS: ACCURACY BY REPRESENTATION

	R1	R2	R3
N	490	492	501
Mean	222.5	220.1	218.2
Median	105.7	94.3	99.2
Standard Deviation	246.9	251.9	245.3

The initial observations based on Table 4.2 indicated that the samples were similar (with regard to mean and median). To select the procedures and tools for analysis and hypotheses testing, the tests described below were performed to identify the distribution of the data.

Classical statistical procedures require a normal distribution of the data and relatively equal variances between the samples. The Kolmogorov-Smirnov (K-S) Goodness-of-Fit[76,77] test was used to assess whether the samples were from a normal distribution.[78] The results of the K-S Goodness-of-Fit tests (Table 4.3) strongly support the rejection of the hypothesis that

[76] To implement the K-S Goodness-of-Fit Test, a MiniTab macro program provided by Coakley (1996) was used.

[77] The assumptions for the K-S goodness of fit test require a continuous distribution with a measurement scale that is at least ordinal. These general assumptions are obviously met.

[78] Other distributions are also tested, but were also not representative of the data.

the samples collected in this experiment are from a normal distribution (all p-values less than or equal to 0.01).[79]

Continuing along the same line of data analysis, the accuracy data by VVIQ level was examined. To begin the ranking of the subjects' VVIQ scores, the scores were sorted. Nineteen subjects' VVIQ scores were incomplete and were eliminated from this segment of the analysis. Of the remaining subjects, the middle one-third[80] was eliminated; the low one-third was coded as Low VVIQ and the high one-third was coded as High VVIQ.[81] This coded data (described in Table 4.4) is required for testing the second hypothesis. In Table 4.5, the results of the K-S Goodness-of-Fit test relating to the VVIQ sample data are presented. Consistent with the accuracy data (by representation) examined above, there is strong evidence that the VVIQ samples are not from a normal distribution.

TABLE 4.3 KOLMOGOROV-SMIRNOV GOODNESS-OF-FIT: ACCURACY BY REPRESENTATION

	R1	R2	R3
Stephens' Modified KS Statistic	4.1893	5.7024	5.1814
Lower limit for p-value	0.000	0.000	0.000
Upper limit for p-value	0.010	0.010	0.010

[79] Several data transformations were made, trying to achieve normality. After the transformations, the data continued to test non-normal.

[80] The middle one-third was an approximation. Of 1,256 observation points with subject VVIQ scores (sorted in VVIQ score order), observations 395-812 were eliminated, representing VVIQ scores of 3.625-4.125. The approximation was used because in the actual middle one-third, break points were not at a break in the VVIQ scores. The group eliminated was extended/reduced to the nearest break in the scores.

[81] Because the VVIQ coding was completed after random assignment to experimental groups, statistical tests were performed to verify that no differences existed in VVIQ scores between the experimental groups.

TABLE 4.4 DESCRIPTIVE STATISTICS: ACCURACY BY VVIQ RANK

	High VVIQ	Low VVIQ
N	395	444
Mean	219.3	219.5
Median	96.1	99.2
Standard Deviation	249.9	248.3

TABLE 4.5 KOLMOGOROV-SMIRNOV GOODNESS-OF-FIT: ACCURACY BY VVIQ RANK

	High VVIQ	Low VVIQ
Stephens' Modified KS Statistic	4.7262	4.7743
Lower limit for p-value	0.000	0.000
Upper limit for p-value	0.010	0.010

The data required to test the third hypothesis were collected based on the time required to make a prediction. Descriptive statistics of these data are reported in Table 4.6. The K-S Goodness-of-Fit test was performed on this data also with the results reported in Table 4.7. The evidence from the K-S test strongly supports rejection of the hypothesis that the sample distribution is normal.

TABLE 4.6 DESCRIPTIVE STATISTICS: TIME BY REPRESENTATION

	R1	R2	R3
N	490	492	501
Mean	26.439	27.27	35.52
Median	20	19	26
Standard Deviation	21.803	28.19	32.70

TABLE 4.7 KOLMOGOROV-SMIRNOV GOODNESS-OF-FIT:
TIME BY REPRESENTATION

	R1	R2	R3
Stephens' Modified KS Statistic	3.7462	4.1300	3.4962
Lower limit for p-value	0.000	0.000	0.000
Upper limit for p-value	0.010	0.010	0.010

After evaluating the evidence indicating support that the samples were not normally distributed, it was determined that the Kolmogorov-Smirnov Two-Sample Test would provide important information relating to the similarity of the distributions among the samples. The K-S Two-Sample Test was performed on each combination of representation/accuracy samples; Table 4.8 contains the results from these tests. The K-S Two-Sample Test is used to test whether the distributions of two samples are equivalent. P-values less than 0.20 are considered strong evidence (Coakley 1996) to support the rejection of this hypothesis. The p-values contained in Table 4.8 support the rejection of the hypothesis that the distribution of the accuracy samples that relate to R1 and R2 are equivalent. Based on this result there is no evidence to support the rejection of an equivalent distribution hypothesis for the R1/R3 or R2/R3 combinations.

From the K-S Goodness-of-Fit and K-S Two Sample tests, it was concluded that it is likely that the accuracy samples based on representation are not normal; additionally the samples may come from at least two different distributions that are unknown to the investigator. Based on these findings, it was determined that the data should be analyzed and research hypotheses tested using nonparametric procedures.[82]

TABLE 4.8 KOLMOGOROV-SMIRNOV TWO SAMPLE TEST (P-VALUE RANGES)

	R2	R3
R1	0.05 - 0.10	0.20 – 1.00
R2		0.20 – 1.00

4.3. Statistical Procedures and Hypotheses Tests

This research manipulated representations using a variety of prediction scenarios. For each of the four case companies, each subject made three predictions, for time periods extending beyond the information provided. One would expect, as the time periods increased (the predictions reaching further into the future) the accuracy of predictions might decline. These expected differences suggest the within-company predictions should be examined individually, rather than in aggregate. In addition to the expected variability within company predictions, a wide variation was expected between companies. This was due to the characteristics of the companies used in the experiment. Two of the companies were designated as “small," and two as “large.” One large and one small company were also selected as “high” and “low” growth companies. Intuitive that the raw magnitude of an error for a large company would be larger than the magnitude of an error for a small company. Due to this expected result, it was determined that the accuracy of the predictions for each company should be examined independently.

[82] A series of classical statistical procedures were also used to evaluate the data. For these results see

In order to evaluate the data independently with respect to company and prediction time "distance", the accuracy data was segmented by observation made by the subjects. Each subject made exactly one prediction for each time period for each company. A model of randomized complete blocks was developed using representations blocked by subject observations. The mean for each block was calculated providing the model with one observation per cell. The data used for this test is included in Table 4.9.

TABLE 4.9 OBSERVATION ACCURACY MEAN (RANK) FOR H1 TEST

Block\Representation	**R1**		**R2**		**R3**	
Company 1: Obs 1	88.4	(3)	87.1	(2)	82.7	(1)
Company 1: Obs 2	107.1	(3)	102.8	(2)	98.8	(1)
Company 1: Obs 3	122.1	(3)	108.6	(1)	118.8	(2)
Company 2: Obs 1	191.7	(3)	186.9	(2)	181.3	(1)
Company 2: Obs 2	112.1	(1)	177.3	(3)	116.5	(2)
Company 2: Obs 3	.9	(1)	29.0	(3)	12.6	(2)
Company 3: Obs 1	.9	(1)	9.7	(3)	1.5	(2)
Company 3: Obs 2	12.5	(3)	.2	(1)	4.4	(2)
Company 3: Obs 3	38.3	(3)	27.6	(1)	33.2	(2)
Company 4: Obs 1	411.9	(3)	398.8	(2)	394.9	(1)
Company 4: Obs 2	581.4	(3)	570.3	(1)	573.3	(2)
Company 4: Obs 3	812.3	(3)	804.7	(2)	802.1	(1)

The first hypothesis to be tested related to differences among mean prediction accuracy for each of the presentation formats. Stated in the null form:

$H1_0$: There is no difference in decision accuracy due to differences in visual representations.

Appendix.

Friedman's Rank Sums Test was used to test the first hypothesis. Friedman's Test is a distribution free test that requires data with one observation per block (Hollander & Wolfe 1973.) The distribution free characteristic is important considering the unknown, non-normal distributions of the samples collected in this research. To test the hypothesis of treatment effect equality, Friedman's Test ranks the observations within a block, and evaluates the rankings for a specific treatment (Hollander & Wolfe 1973.)

Friedman's Test (Table 4.10), using the representations as treatments, results in a p-value of .076. This provides some evidence that there are differences among the treatments. To use this evidence, one must consider the power of the test used. The power of a statistical test has been defined as "the probability of its rejecting a specified false hypothesis" (Bradley, 1968, p. 56). Bradley (1968) suggests power depends on four variables, including the alpha level of the hypothesis test and the size of the experimental sample. Efficiency has been defined as "a relative term comparing the power of one test with that of a second test which acts as a standard of comparison and is often the most powerful test for the conditions under which the comparison is made." (Bradley, 1968, p. 57) The efficiency range of Friedman's test relative to a test that is optimal under normal-theory conditions is .637 - .995 (Bradley, 1968, p.60). This efficiency rating suggests that to achieve the same statistical power of a hypothesis test using Friedman, the corresponding classical procedure may only require 63.7 percent of the number of subjects in the sample. Likewise, to provide the same power as the classical procedure, a sample size increase of 57 percent may be required when using Friedman's test.

In this research, increasing the sample size would have increased the power. Because of the limited size of the classes from which the subjects were selected, and funding limitations, the sample size could not be increased. The combination of the relative inefficiency of the Friedman test (above) and the suggestion that within the field of nonparametric statistics, p-values within the range of .05 and .10 provide mild evidence in favor of rejecting a null hypothesis (Coakley, 1996), leads the investigator to reject $H1_0$.

Figure 1, a graphic display of the mean ranks for each of the representations, is consistent with this evidence. While this evidence supports rejection of H1o, a major issue in this research concerns not merely the existence of treatment differences, but the direction of those differences.

The next logical step was an investigation of the direction of the differences among the treatments. As described in Chapter 2, it was expected that R3 would provide the highest accuracy of the treatments, R2 the mid-range of accuracy, and R1 the lowest accuracy. With this expectation, Page's (1963) test for ordered alternatives in a two-way layout was used to test for the direction of the relationships.[83]

Page's test is a distribution-free test [84], based on the Friedman rank sums test. While Friedman's test is used to look for the *existence* of differences between treatments, Page's test is used to evaluate the *order* of those differences; the order should be identified prior to performing the test. Each block is ranked by the relative position among the treatments. The sum of the ranks for a treatment is computed and multiplied by a factor based on the expected

[83] To implement Page's test, a MiniTab macro program, provided by Coakley (1996) was used.

[84] A distribution free test was used because the distribution of the sample data was unknown.

order; those products are summed, yielding the test statistic.[85] Rankings used in the computation of the Page test statistic are presented in Table 4.9. The results of this performing of Page's test are included in Table 4.11.[86] The range of the p-values ($0.01 < p \leq 0.05$) suggests strong support for the order of accuracy of representations $R3 \leq R2 \leq R1$, where at least one of the inequalities is not a strict equality. Figure 2, is a graphic that displays the number of instances each representation is ranked first, second or third. The graph is consistent with the results of Page's test; the 3D Rotatable image was not ranked third in any experimental block, while it was ranked first and second more times than either the 2D or 3D Static images.

Evidence from Page's test, in conjunction with the result from the Friedman test, and Figure 2, supports the rejection of the null hypothesis (H1o) and is consistent with the alternative that proposes increased accuracy of predictions using multi-dimensional representations of multi-dimensional data. Based strictly on the sample means, as displayed in Table 4.2, it also appears that the raw data are also directionally consistent with the results; R3 predictions are more accurate (smaller error mean) than R2 predictions which are more accurate than R1 predictions.

Results from these tests are consistent with several streams of research. First, presentation format importance is confirmed. Anderson and Reckers (1992), MacKay and Villarreal (1987) and Stock and Watson (1984) all found that differences in decisions occur, based on the format data is presented to the decision-maker. Wickens, Merwin & Lin's

[85] Hollander & Wolfe (1973) provide several examples of this computation.

[86] P-values obtained from Hollander & Wolfe (1973, 372).

(1994) research indicating that 3D images are superior to 2D images when subjects are required to extract data. The current study confirms more accurate decisions are made when using 3D images rather than 2D images. Within the area of accounting, the current study findings are consistent with the preferable decision outcomes when using multidimensional representations (MacKay & Villarreal 1987; Moriarty 1979; Stock & Watson 1984.)

TABLE 4.10 FRIEDMAN'S TEST RESULTS

Mean	**Treatment**	**Block**	**Test Statistic**	**P-value**
Accuracy	Representation	Observation	5.17	.076
Accuracy	VVIQ Level	Observation	0.00	1.00
Time	Representation	Observation	15.5	.001

TABLE 4.11 PAGE'S TEST RESULTS

Mean	**Treatment**	**Block**	**Test Direction**	**Test Statistic**	**P-value Range**
Accuracy	Representation	Observation	$R3 \leq R2 \leq R1$	155	$.01 < p \leq .05$
Time	Representation	Observation	$R3 \leq R2 \leq R1$	129	$.05 < p \leq 1.00$
Time	Representation	Observation	$R1 \leq R2 \leq R3$	159	$.001 < p \leq .01$

In addition to the representation treatment effect, the study was used to examine data with regard to the individual subject's visual acuity. The null statement of the second hypothesis, $H2_0$, asserts that visual capability would not be significant with regard to the accuracy of predictions.

$H2_0$: There will be no difference in decision accuracy due to individual visualization capabilities.

The test of $H2_0$ included procedures similar to those described above for testing $H1_0$. In the previous section, the data for this analysis was described and determined to be of a distribution other than normal. Friedman's test was used with the VVIQ samples, using the same blocking factors described for the accuracy by representation data.[87] The results of Friedman's test are included in Table 4.10. The p-value (1.0)[88] provides no support to reject the null hypothesis; this indicates that there are no differences related to the VVIQ treatments.

The lack of support relating to the second hypothesis suggests that visual ability does not affect subjects' ability to make predictions based on graphical data. This result is not consistent with prior behavioral studies (Marks, 1973; Kosslyn, Behrmann & Jeannerod, 1995.) This lack of consistency may be attributable to the visual representations used to convey the data, or the appropriateness of the VVIQ within the context of this study.

Vessey's (1991) cognitive fit model suggests that based on the problem, certain types of representations are a better fit for making decisions. It is possible that the visualization used in this experiment is neutral with regard to the perceptual abilities required to make the predictions in this study. Either the visual abilities required to solve the problem are not measured by the VVIQ, or the visual abilities required are addressed adequately by the visualization, removing them from being a significant factor in the experiment.

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[87] In addition to test of the VVIQ data with the responses categorized as high/low, an additional test was performed using the VVIQ scores as continuous data. The results of this alternate test were not materially different from the reported results.

[88] The p-value is a direct result of equal rankings for the sample and a test-statistic = 0. The two VVIQ treatment samples had equal ranking within Friedman's test, driving the zero value of the test statistic.

The analysis to this point has considered accuracy as the dependent variable. The third hypothesis, $H3_0$, is based on the length of time that subjects took to make their predictions. Stated in the null:

$H3_0$: There will be no difference in time taken to make decisions due to different visual representations.

$H3_0$ hypothesized that the treatment had no effect on the time required to make a prediction. The previous section also described the samples of times collected for the evaluation of this hypothesis. Again, the non-normality of the samples indicated nonparametric procedures were a better fit than classical procedures, for these data. Consistent with the accuracy by representation treatment model (used to test $H1_0$), Friedman's test was executed on these samples, based on decision time, by representation treatment, blocked on the twelve predictions made by individuals. The means and ranks used to test this hypothesis are included in Table 4.12.

TABLE 4.12 OBSERVATION TIME MEAN (RANK) FOR H3 TEST

Block \Representation	**R1**	**R2**	**R3**
Company 1: Obs 1	45.4 (1)	50.3 (2)	52.6 (3)
Company 1: Obs 2	25.9 (2)	22.6 (1)	35.1 (3)
Company 1: Obs 3	19.3 (2)	15.4 (1)	29.4 (3)
Company 2: Obs 1	43.4 (2)	42.1 (1)	52.9 (3)
Company 2: Obs 2	22.0 (2)	21.9 (1)	32.4 (3)
Company 2: Obs 3	20.3 (2)	15.6 (1)	22.6 (3)
Company 3: Obs 1	39.3 (1)	47.7 (2)	53.5 (3)
Company 3: Obs 2	18.9 (2)	17.6 (1)	41.2 (3)
Company 3: Obs 3	14.6 (1)	17.0 (2)	21.4 (3)
Company 4: Obs 1	30.3 (1)	44.9 (3)	42.3 (2)
Company 4: Obs 2	22.5 (2)	18.8 (1)	25.0 (3)
Company 4: Obs 3	15.2 (2)	13.4 (1)	16.8 (3)

The results of Friedman's test are included in Table 4.10. The results of this test indicate strong support (p-value = 0.001) for the rejection of the hypothesis of no treatment differences with respect to prediction times. Figure 3, displays the mean ranks for each of the representations. Based on this graphic, differences exist for the decision time ranks. This evidence of time differences is consistent with prior research suggesting that time differences exist when using multiple forms of information to solve problems (Benbasat & Dexter 1985.) Cooper (1990) also reported that different thought processes are used (suggesting possible time differences) when 2D versus 3D representations are used to solve a problem. With this evidence of treatment differences, it was appropriate to perform an additional test with regard to the direction of the differences. The alternative to $H3_0$ suggested that predictions based on 3D Rotatable representations would take less time than those made based on 3D Static representations, which would take less time than predictions based on 2D representations. Page's test was used to test this order of differences. The results (Table 4.11) do not provide support for that order of differences. The strength of the results from Friedman's Test indicates additional consideration of the cause of the differences may be warranted.

During the experiment, the researcher periodically, informally observed the subjects performing the task. This observation was accomplished without disturbing the subjects and therefore not biasing any of the results. The researcher noted that subjects using R3 appeared to use a significant amount of time rotating the image and observing the graphic from multiple viewpoints. This observation was followed up by a high level analysis of the audio tapes recorded during the experiment. By listening to a small random sample of the tapes, the experimenter verified that subjects given the rotatable image appeared to rotate the image multiple times prior to making their predictions.[89] Comments, other than those relating to the rotation, were similar among the groups.[90] This led to the conclusion that if rotation of the image is required to understand the relationships among the data, the rotation process and the mental adjustment to the new viewpoint may increase the total time to make a decision. Based on this idea, Page's test was run again with the order changed to indicate the times required for the decision process ($R1 \leq R2 \leq R3$.) The results (Table 4.11) strongly support this direction of the results. With regard to the third hypothesis, there is evidence that prediction time differences result from the different treatments, but the differences are in the opposite direction from the initial hypothesis of this research. Figure 4, demonstrates the number of occurrences when each representation is ranked first, second and third for the observation blocks. It is clear from the graphic that the 3D Rotatable visualization ranked last in speed for all but one block. This view of the data suggest that factors other than those originally asserted in the third hypothesis may have influenced the outcome of this segment of the experiment.

One factor that may have affected the time is the process by which decision-makers make decisions. Tan and Benbasat's (1995) study relating to decision-making using 2-dimensional graphs describes the process used to make a decision. The process includes

[89] During the recordings, participants commented about the speed of the rotation of the image, and noted that it was difficult to get the image to stop in the exact position in which they wanted to see the graphic. Even when the rotation was not verbalized, mouse clicks indicating rotation of the image were audible on the tapes.

[90] This indicates on the surface that the improved accuracy from using the rotatable image was not a function of the subjects taking more time, but rather the increased time was a function of the actual representation used in the experiment.

anchoring, disembedding, and projecting, data points and values. Although the interactions of the data are more salient with a 3D representation, it is possible that the process of extracting data from the graphic is more complicated, and therefore more time consuming. Research in the area of the 3D decision-making process may provide insight to the intricacies of this issue.

Conclusions based on the results presented in this chapter, along with the limitations of this research and directions for future research are discussed in Chapter 5.

CHAPTER 5

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Chapter 4 was used to present the results of the experimental analysis, test the hypotheses discussed in Chapter 2, and discuss the consistency of these results within the body of literature associated with visual representations of accounting and behavioral data. This chapter draws conclusions from the results, discusses the limitations of this research and suggests future research directions based on this investigation.

5.1. Conclusions

The results of this study indicate that the form of the representation of data affects the accuracy of predictions based on that data. Additionally, one can conclude that complex multi-dimensional data may be used to make decisions that are more accurate if the data is represented in a multi-dimensional format that allows the direct examination of the data relationships. This has implications within the realm of accounting with respect to decision-making when multiple variables are involved. As the decision criteria increases in complexity,[91] there should be representations that show the interactions among the variables to help the decision-maker make better[92] decisions.

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[91] In this instance, complexity is operationally defined as dimensionality.

[92] Better, being defined here as more accurate.

One practical application of this research is in the audit environment. Fischer (1996) suggests that new technologies should be adopted to enhance audit evidence. Auditors must look at information individually and in an aggregate to make decisions. Multidimensional visualizations may help the auditor understand the interactions and complexity of the audit data, thereby reducing decision error relative to the audit. Improved understanding of data relationships and better accuracy for decisions would be welcomed by auditors and those that rely on their opinions.

Although the decision accuracy was improved by using the 3-D formats, the results do not indicate that in this instance, decision-makers use less time in forming their conclusions when using these higher-dimension representations. The results do indicate that differences exist in the decision time, but these differences may be due to the physical limitations of rotating the graphic or other factors not investigated here. One of the factors that may affect the increased time for a 3D representation, may be the increased complexity in disembedding and projecting of the data, key factors in the decision process (Tan & Benbasat, 1993.) This increased complexity may add time to the decision-maker's interpretation time. Another possible explanation of the data differing from the expectations relates to training of the subjects. It is possible that the subjects were not comfortable with the complexity of the task, and therefore took more time to investigate and understand the visualizations. From a practical point of view, this study indicates that one should consider the interpretation time factor when designing and developing visualizations.

In addition to the differences in prediction accuracy and time, based on the various representations of the data, this study was used to examine accuracy differences based on individuals' visual acuity. The results were inconclusive regarding this topic. This study found no difference between the prediction accuracy for the high and low visual acuity groups. This lack of findings, although inconsistent with prior literature (Marks 1973), may be accurate based on the type information provided to, or the type decision made by the subjects. Before accepting this result, this issue should be investigated possibly using other measures of visualization abilities.

5.2. Limitations

One issue frequently in the forefront of visualization research is the appropriateness of a visual representation for a specific problem. Vessey's (1991) cognitive fit theory suggests that based on the type of problem there is a preferred representation of the data that can be used to effectively solve the problem. There is a possibility that better visualizations (one that assists decision-makers in making more accurate, faster decisions) exist for the momentum accounting problem addressed in this dissertation.

Even if the visualizations used in this study are optimal for the problem investigated, the findings are limited to data with less than five dimensions. No attempt was made to develop an n-dimensional representation model where n is greater than four.

The problem space, momentum accounting, also may be used to raise a question with regard to the limitations of this research. Although an interesting, complex problem, there are currently no systems in use based on momentum accounting; this study was based on a simulation of momentum accounting information generated from market value based accounting information. The results of this study are limited, based on the assumption that this simulation is not materially different from actual information that would be produced with a momentum accounting system.

Operating under the assumptions that this study used visualizations that are optimal representations of momentum accounting information, and the simulated information is an acceptable proxy for a momentum accounting system, other limitations can be identified within the experiment. First, the issue of visual impairments and color-blindness were not considered. It is possible that basic sight problems such as these may affect an individual's ability to use the presentations to make decisions. This should not have affected the overall results, but it is possible that the results would be different for such a segment of the population. Screening of applicants could be used in future research to control for this limitation. The next limitation is concerned with the testing for visual acuity; only one test of visual vividness was used. Others exist, and should be tested within the framework of accounting problems. No significance was reported based on the VVIQ; this may be tied to the specific test, or may be a valid result that would occur without regard to the measurement instrument.

In addition to individual difference limitations, there may also be differences between the individuals that participated in the study and the managers for which they were used as proxies. The limitation of using student subjects has been debated for decades with no definitive conclusion.[93] For this research, it is believed that differences between the groups is minimal; neither group had prior knowledge of momentum accounting concepts or 3-

dimensional visualizations of accounting information, because neither of these concepts are currently used in academia or industry.

5.3. Future Research Directions

This dissertation is an initial investigation of three-dimensional visualizations used in an accounting environment. The data were obtained using the complex information from a simulated momentum accounting system. There are several issues relating to visualizations of accounting information and momentum accounting that warrant future investigation.

5.3.1. Visualization in Accounting

A classification of accounting issues into categories that relate to the appropriateness of various presentation formats would provide a useful direction for future research. General categories of visualizations have been developed (Lohse et al 1994), but research of this type, in the area of accounting does not exist. Such a classification would allow for the focus on presentation development for specific areas within the categories.

Regardless of the type of problem to be solved, when developing visualizations a question regarding the appropriateness of the data presentation always exists (Vessey 1991, Lohse et al 1994.) This study used three methods of presenting the data; the experiment supported differences in the effectiveness of predictions based on these representations. A useful stream of research would include the development of a system of representations that provide reliable information to the users of accounting information. These representations

[93] Gordon, Slade & Schmitt (1986) reviewed 32 studies that included student subjects and non-students. Overall, the findings were mixed. They acknowledged the practice of using student subjects will probably

could be developed based on the types of accounting decisions required from information, and should be developed considering the cognitive styles of accounting systems users. They might include text, simple graphics or technologically advanced interactive visualizations.

As technology continues to advance, accounting system researchers should maintain currency with respect to methods of data presentation. As virtual reality systems are adopted in other venues, they may appropriately be used to enhance the decision-making capabilities of accounting information users under a wide set of decision issues, internal and external to an organization.

This study was limited to an accounting prediction problem based on momentum accounting information. Because of the limitations of using momentum accounting, future research should include the investigation of traditional accounting concepts and issues in conjunction with the corresponding momentum accounting topics.

5.3.2. Momentum Accounting

This research used momentum accounting as a problem space to which visualizations were applied. It did not address the usefulness of the momentum accounting information or its desirability for implementation in organizations. Additional investigations should be pursued to compare decisions made using momentum accounting information with those made using traditional systems. This could be accomplished by testing the incremental information provided by momentum accounting systems, such as the first and second derivatives of wealth.

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continue because students are generally a low cost alternative.

If momentum accounting systems are demonstrated to provide information that is superior to traditional accounting systems, a new stream of research should include effective development, implementation and use of momentum accounting systems.

5.3.3. Visual Differences

Previous research has demonstrated differences among individuals, based on their visualization abilities.[94] Future research should include the adaptation of measures of these differences, other than the VVIQ, to measure this factor and study the users of accounting information. It might be of interest to compare these users and their capabilities with the general population of people and evaluate the importance of this factor in an accounting environment.

5.3.4. Decision Process

Prior literature on decision processes has primarily been limited to the 2-dimensional graphics area (Tan & Benbasat, 1993.) This literature base needs to be updated to include an investigation of the decision-making process when 3-dimensional (and higher) data representations are used (Benbasat, 1997). The similarities and differences between 2-dimensional and 3-dimensional representations within a decision-making framework should be compared and contrasted to aid in the understanding of the processes.

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[94] Marks (1977) provides review of the research in this area.

5.4. Summary

Several contributions have come from this research. First, this study expands multidimensional graphics representations into the accounting information systems literature. Previously only studies using 2-dimensional representations had been examined.[95] This new direction was driven by technological advances that have been adopted in other fields, but are absent from the accounting systems literature. This contribution was accomplished through the generation and use of 3D representations and the comparison of these representations to 2D presentations of the same data. The results show that in a complex data environment, 3D representations can be more useful than a corresponding 2D representation. This is important as the complexity of the accounting environment increases.

This increasing complexity has caused accountants to look for new ways to track and report financial information for organizations (Ijiri, 1982). The examination of complex momentum accounting information for the purpose of making decisions is a contribution of this research. This examination is important because little is known about the topic. To determine if the concepts are useful, an understanding of the components must be developed. In the current study, this was accomplished by the development of visualizations to aid decision-makers in understanding and using this information; they were able, without direct knowledge of momentum accounting, to make decisions based on these representations. This method of data presentation assisted in the simplification of momentum accounting concepts and is an increment in the process to better understanding momentum accounting.

[95] The exception to this was the Chernoff faces literature which used a 2D image with multiple characteristics (Chernoff, 1973).

The final contribution is one of assisting in the adaptation of techniques used in other arenas to problems in the field of accounting. This study used technologically advanced tools that were primarily developed for and used to study problems in the physical sciences. By adapting such tools, accounting researchers may increase their effectiveness when studying information system issues.

APPENDIX

RESULTS OF MANOVA TESTS

As part of the statistical analysis, a series of test were run using the data collected to test the first hypothesis. A SAS program[96] was developed to block the sample data on subject observations consistent with the blocking described in Section 4.3. After the blocking, the program was used to perform a multivariate analysis of variance (MANOVA) using the experimental data. Results from the MANOVA tests are included in Table A.1.

TABLE A.1 RESULTS FROM MANOVA TESTS

Representation Differences /p-values	Wilks' Lambda	Pillai's Trace	Hotelling-Lawley Trace	Roy's Greatest Root
Overall	.0393	.0410	.0377	.0093
R1 vs. R2	.0341	.0341	.0341	.0341
R1 vs. R3	.5204	.5204	.5204	.5204
R2 vs. R3	.0301	.0301	.0301	.0301

The results from the MANOVA tests suggest rejection of $H1_0$, based on the p-values reported in Table A.1. They further indicate that the differences among the representations exist between R1/R2 and R2/R3 but not between R1/R3. These results are not consistent with the ranked data presented in Table 4.9, using the same blocking criteria. It is believed the inconsistency is based on the violation of the homogeneity of variance assumption required

[96] The complete program is included in Exhibit 13. It includes a transformation based on taking the natural log of the squared errors, in an attempt to normalize the data.

for the MANOVA tests. These findings and inconsistencies added to the evidence favoring the nonparametric procedures used to ultimately analyze the data for each of the hypotheses.

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FIGURE 1

Accuracy Mean Ranks by Representation

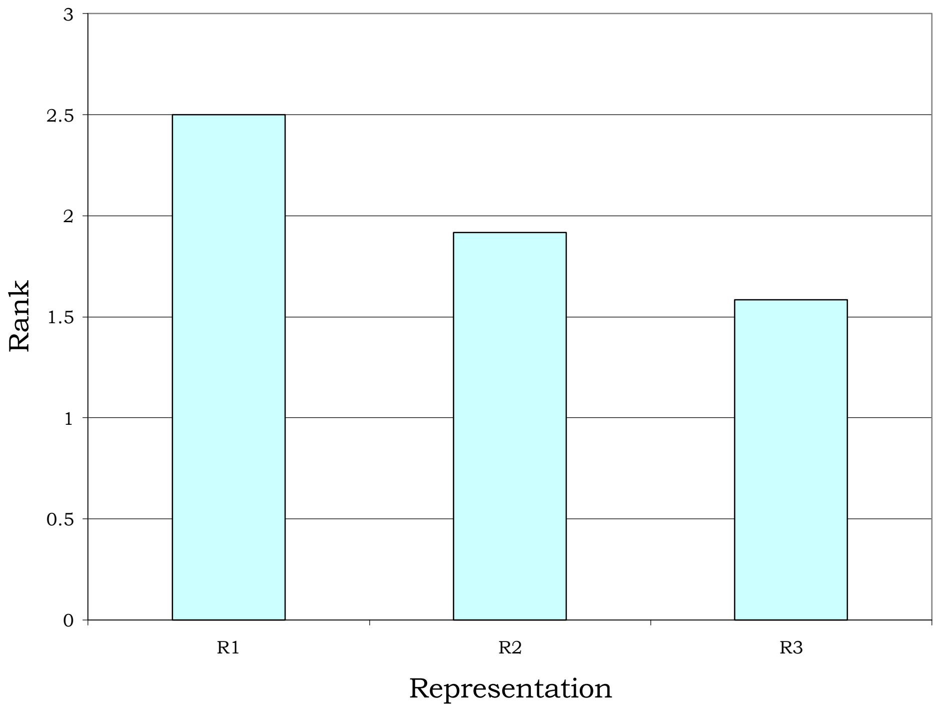

FIGURE 2

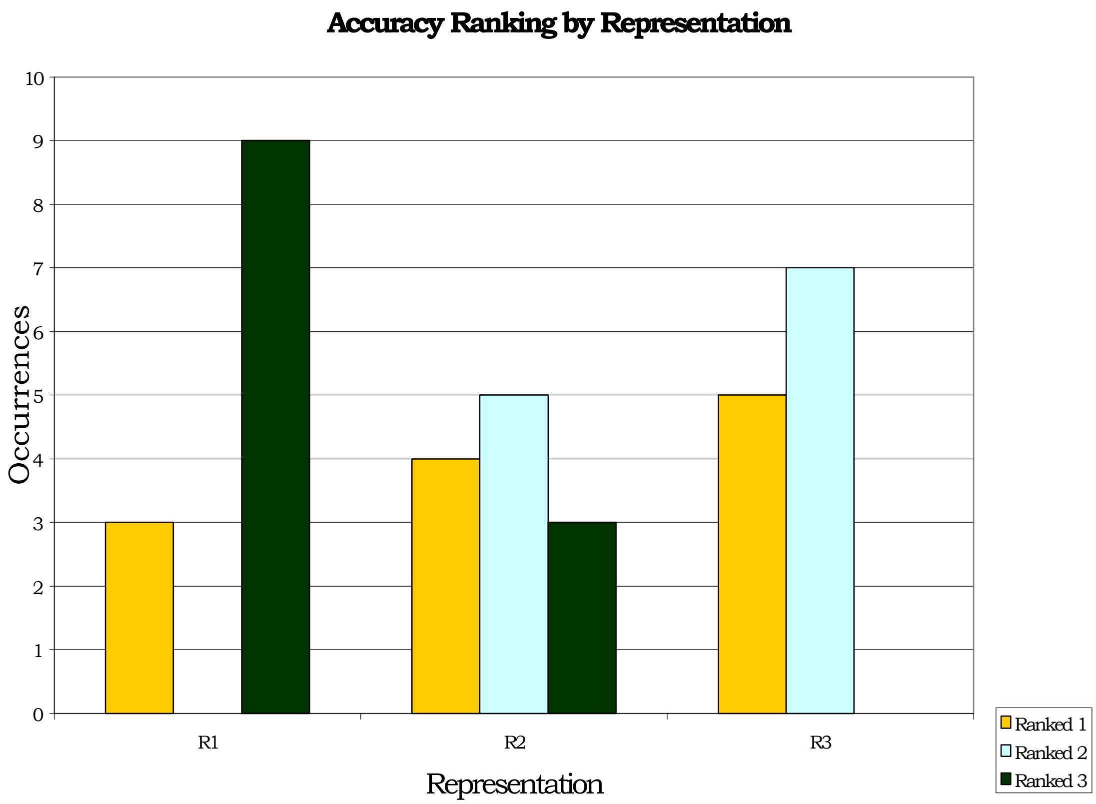
Accuracy Ranking by Representation
Occurrences
0
1
2
3
4
5
6
7
8
9
10
R1
R2
R3
Representation
Ranked 1
Ranked 2
Ranked 3

FIGURE 3

Speed Mean Ranks by Representation

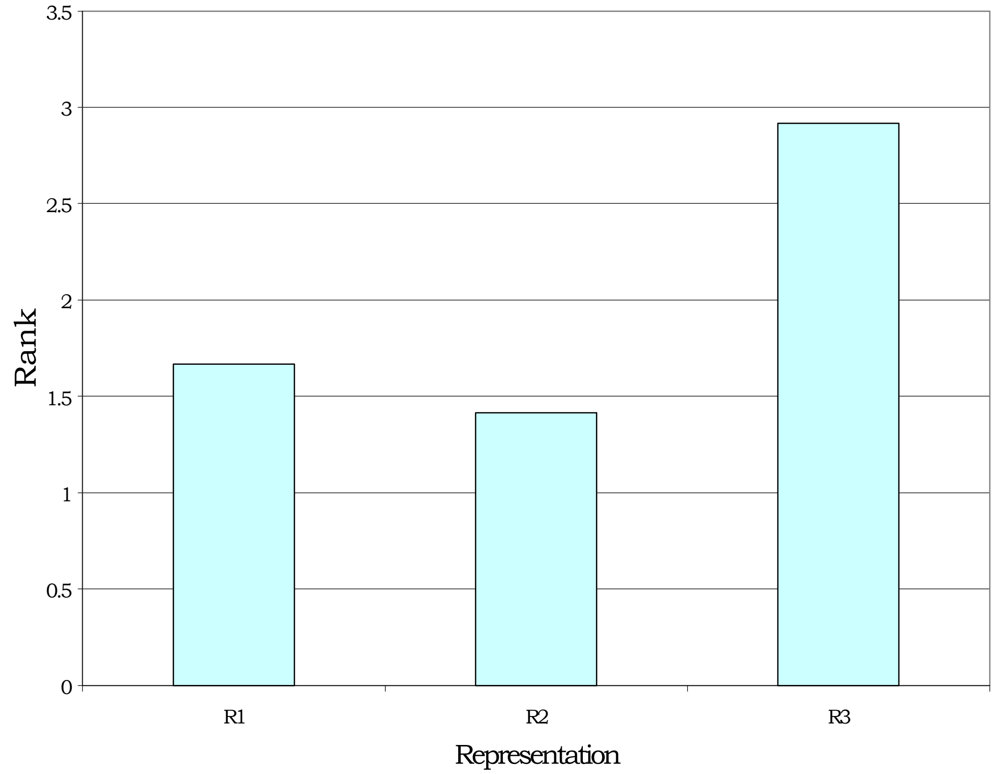

FIGURE 4

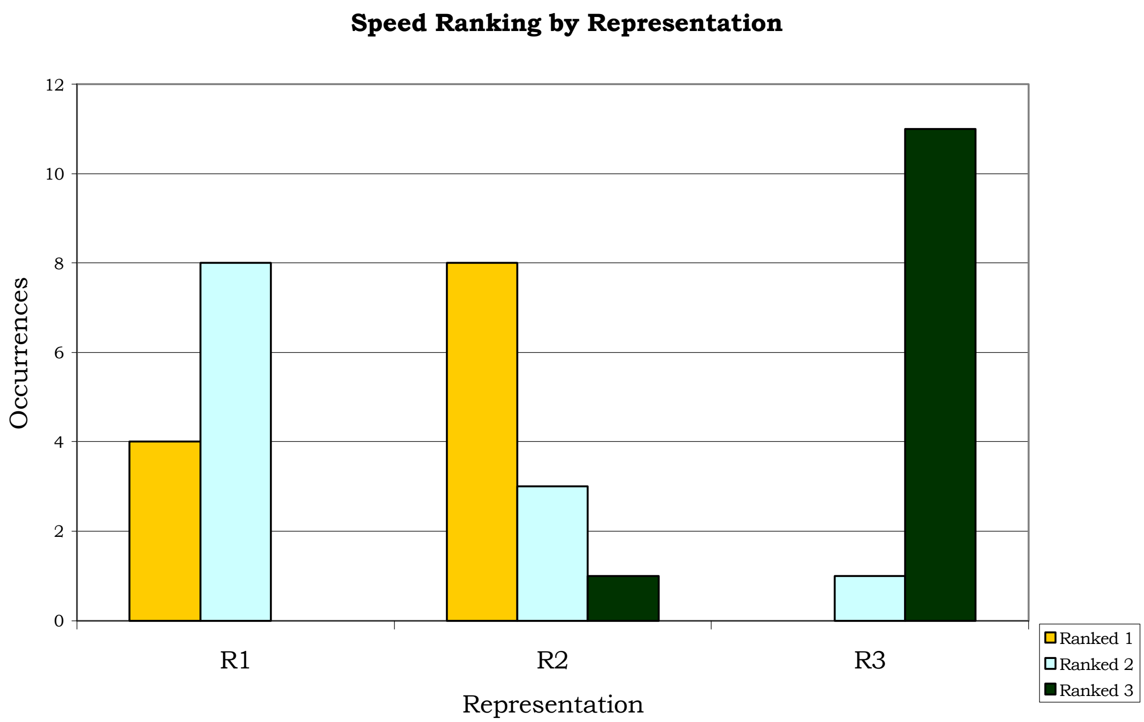
Speed Ranking by Representation
12
10
8
6
4
2
0
Occurrences
R1
R2
R3
Representation
Ranked 1
Ranked 2
Ranked 3

EXHIBIT 1

R1 – 2 Dimensional Representation of Accounting
Wealth, Momentum and Impulse

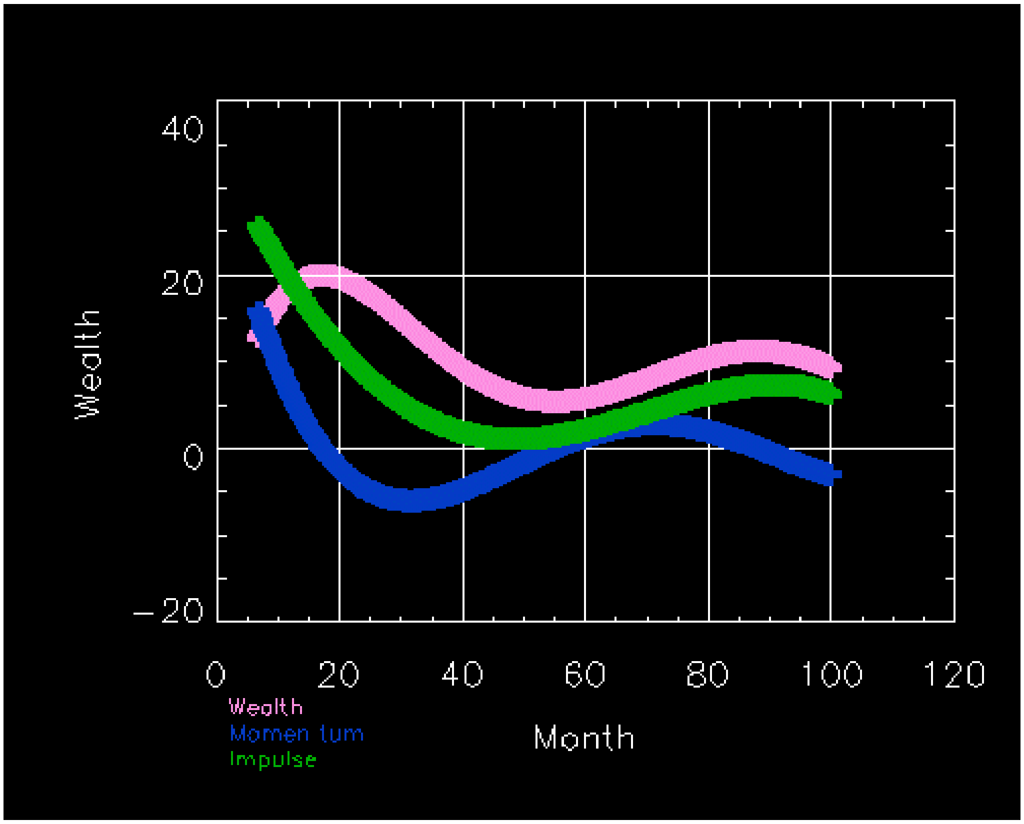

EXHIBIT 2

R2/R3 – 3 Dimensional Representation of Accounting
Wealth, Momentum and Impulse

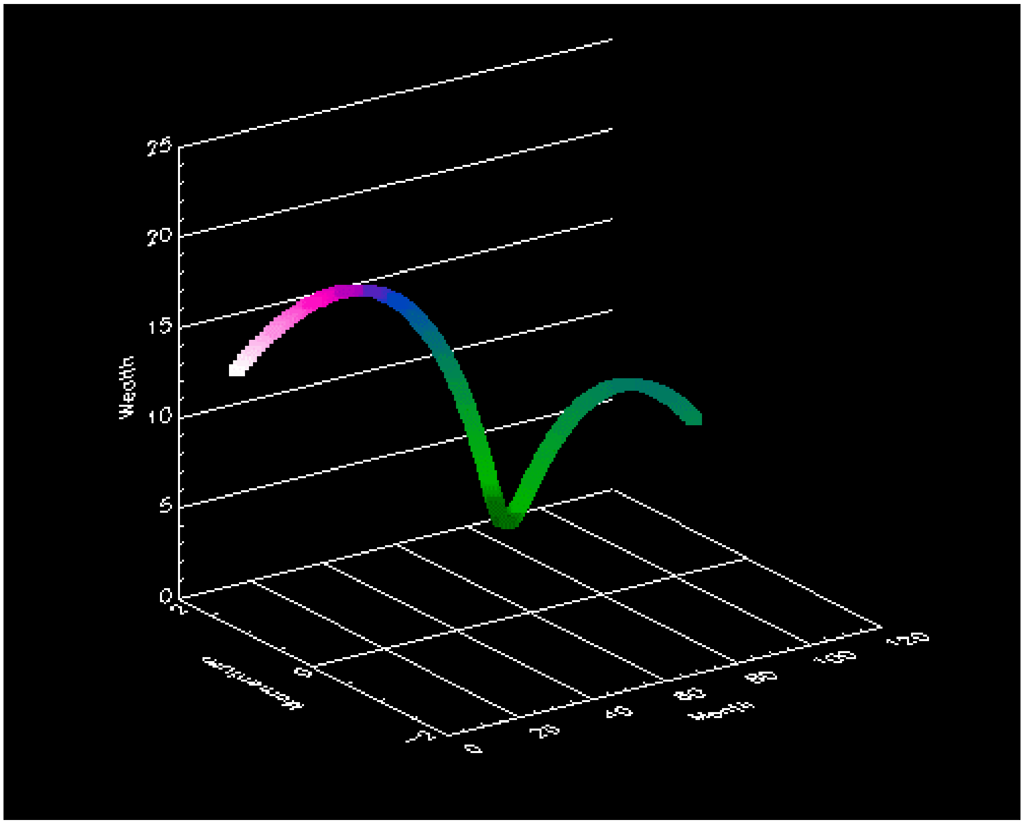

EXHIBIT 3

PV-WAVE PROGRAM TO GENERATE R1 IMAGES

```
;portions of this program were adapted from a program written by Tracy Hess, Virginia Tech,
Blacksburg, VA.

;creates 1 image of a 2-D lineplot.

PRO cfr1
;
status=dc_read_free('cfr1data.csv',$
        month,wealth,moment,imp,/col)
loadct,10
;
bz=0

;set up the graph characteristics including axes, heading and scales

for k=1,1 do begin
        window,0,xsize=500,ysize=400,title="Weath Visualization 2-Dim"
        bx=0
        ndgr=5
        ;
        openw,4,'temp.dat'
        if (k lt 10)then printf,4,format='(i1)',k
        if (k ge 10)then printf,4,format='(i2)',k
        close,4
        openr,4,'temp.dat'
        nn=''
        readf,4,nn
        if (k lt 10)then pp="cfr10"+nn+".bmp"

        close,4
        plot, month, wealth,/Nodata,xrange=[.25,120],yrange=[-7,25],$
                ticklen=1,background=32,color=255,charsize=1.5,$
          xTitle="Month", yTitle = "Wealth",$
          /noerase

; plots three lines on the graph

        oplot, month, wealth,color=224, psym=1,$
```

```
            linestyle=0,thick=4
        oplot, month, moment,color=124, psym=1,$
            linestyle=0,thick=4
        oplot, month, imp,color=24, psym=1,$
            linestyle=0,thick=4

; create the legend
        ;
        lltype = [0,0,0]
        lline = ['Wealth', 'Momentum', 'Impulse']
        lcol = [224,124,24]
        Legend, lline, lcol, lltype,0,-10,-30,3
        ;

        status=wwrite_dib(filename=pp)
        bz=bz+ndgr
        ;wdelete

        endfor
;zmargin=[1,2],

end
```

EXHIBIT 4

PV-WAVE PROGRAM SEGMENT TO GENERATE R2/R3 IMAGES

;portions of this program were adapted from a program written by Tracy Hess, Virginia Tech, Blacksburg, VA.

;creates 1374 images of a 3-D lineplot

;the image generation begins perpendicular to the y axis (90 degrees from ;the x-axis) and generates 72 images, with 5 degree increments around the y ;axis.

;next the angle from the x-axis (variable bx)is decremented by 5 degrees and ;72 more images are generated, in 5 degree increments around the y axis.
;this process continues, executing the program segment, decreasing the ;angle from the x-axis, until (and including the loop where) bx=0.

```
PRO cc01_19
;
; open the datafile and read the four columns of data
;
; start of program segment
;
status=dc_read_free('ccdata.csv',$
        month,wealth,moment,imp,/col)
loadct,10
;
bz=0

for k=1,72 do begin
        window,0,xsize=500,ysize=400,title="Weath Visualization"
        bx=90
        ndgr=5
        ;                 create files for each image in the series
        openw,4,'temp.dat'
        if (k lt 10)then printf,4,format='(i1)',k
        if (k ge 10)then printf,4,format='(i2)',k
        close,4
        openr,4,'temp.dat'
        nn=''
        readf,4,nn
```

```
        if (k lt 10)then pp="cc010"+nn+".bmp"
        if (k ge 10)then pp="cc01"+nn+".bmp"
        close,4

; setup the grid, including axes and legends
        surface, findgen(2,2), /Nodata, $
                /Save,xrange=[.25,120],yrange=[-35,45],$
          zrange=[0,850],ticklen=1,background=32,color=255,charsize=1.5,$
          xTitle="Month", zTitle = "Wealth",$
          yTitle="Momentum", zvalue=0,/noerase,ax=bx, az=bz

; plot the 3D line, with the value of color equal to the impulse value

for m=1,372 do begin
        plots,month(m),moment(m),wealth(m),/T3d,color=imp(m), psym=1,$
        linestyle=0,thick=4
        ;
endfor
        status=wwrite_dib(filename=pp)
        bz=bz+ndgr
        ;wdelete

        endfor
;zmargin=[1,2],

                                    ;end of program segment
```

EXHIBIT 5

VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE
Form 1

For each of the following suggested images, please rate its vividness in your mind's eye as follows:

1. No image at all, you only "know" that you are thinking of the object
2. Vague and dim
3. Moderately clear and vivid
4. Clear and reasonably vivid
5. Perfectly clear and as vivid as normal vision

For items 1-4, think of some relative or friend who you frequently see (but who is not with you at present) and consider carefully the picture that comes before your mind's eye.

Item						
1.	The exact contour of face, head, shoulders and body.	1	2	3	4	5
2.	Characteristic poses of head, attitudes of body, etc.	1	2	3	4	5
3.	The precise carriage, length of step, etc., in walking.	1	2	3	4	5
4.	The different colors worn in some familiar clothes.	1	2	3	4	5

For items 5-8, visualize a rising sun. Consider carefully the picture that comes before your mind's eye.

Item						
5.	The sun is rising above the horizon into a hazy sky.	1	2	3	4	5
6.	The sky clears and surrounds the sun with blueness.	1	2	3	4	5
7.	Clouds. A storm blows up, with flashes of lightning.	1	2	3	4	5
8.	A rainbow appears.	1	2	3	4	5

For items 9-12, think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

Item						
9.	The overall appearance of the shop from the opposite side of the road.	1	2	3	4	5
10.	A window display including colors, shapes and details of individual items for sale.	1	2	3	4	5
11.	You are near the entrance. The color, shape and details of the door.	1	2	3	4	5
12.	You enter the shop and go to the counter. The counter assistant serves you. Money changes hands.	1	2	3	4	5

Finally, for items 13-16, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

Item						
13.	The contours of the landscape.	1	2	3	4	5
14.	The color and shape of the trees.	1	2	3	4	5
15.	The color and shape of the lake.	1	2	3	4	5
16.	A strong wind blows on the trees and on the lake causing waves.	1	2	3	4	5

EXHIBIT 5A

INTRODUCTION TO THE VVIQ

To help analyze the data from the experiment, we need to find a basis of comparison between individuals for visual vividness capabilities. The following questions have been used in many research projects for this purpose. Please answer each question to the best of you ability.

EXHIBIT 6

PARTICIPANT REWARD SYSTEM

Your compensation for the study will be $6.00 per hour and will be paid at the end of the session. Additionally, each subject will be entered into a prize drawing based on the accuracy and speed of their responses. There will be two bonuses ($75 and $25) for each of the four groups of subjects. For the purpose of the bonus drawing, you will only be compared to others within your group. If your accuracy rate is in the top 25%, second 25%, third 25% or bottom 25%, you will receive four, three, two or one chance(s) in the drawing. Additionally, if you accuracy rate is in the top 50% of your group, you can get bonus chances for the drawing, based on how quickly you completed the task. The following grid shows precisely how many chances you may have to win.

		Number of entries for bonus prize				
		Speed Bonus (only for top 50% accuracy)				
	Speed->	Top 25%	2nd 25%	3rd 25%	Bottom 25%	
Accuracy	*Chances*	4	3	0	0	
Top 25%	4	8	7	4	4	
2nd 25%	3	7	6	3	3	
3rd 25%	2	2	2	2	2	
Bottom 25%	1	1	1	1	1	

The drawing for the bonus will occur at the end of the data collection period (expected to be prior to May 8, 1997). The winners will be notified by phone or e-mail. If you are a winner, your name may be released as being a winner to other participants, although no indication of your performance of the task will be disclosed.

In addition to the monetary compensation, each subject will receive a bonus of 1% of the course grade for the course from which they are recruited. An alternate method of earning the credit will be given for those choosing not to participate.

EXHIBIT 7

DEMOGRAPHIC QUESTIONS

To provide better insight into the data, please provide the following demographic information:

How old are you (in years)?

What is you sex (F or M)?

How much computer experience do you have (in years)?

How much work experience do you have (in years)?

How many years of college have you completed?

What is the highest degree you have earned?

How many math courses have you had in college?

What is your current major?

EXHIBIT 8

POST TASK QUESTIONS

Please answer the following questions relating to the experimental task that you just completed (predictions for the four companies). Use the mouse to click on the number 1,2,3,4 or 5 based on your response.

(Scale: 1=Agree strongly, 2=Agree somewhat, 3=Do not agree or disagree, 4=Disagree somewhat, 5=Disagree strongly)

I understood the tasks I was asked to perform.

I understand the concept of wealth.

My wealth predictions are not accurate.

I do not understand the concept of momentum.

My momentum predictions are accurate.

I understand the concept of impulse.

My impulse predictions are accurate.

I enjoyed the task.

I would not enjoy performing the task again.

I believe that math skills would help perform the task.

My math skills are good.

I have a thorough understanding of Accounting.

Graphics are difficult to interpret.

My calculus skills are good.

EXHIBIT 9

INFORMED CONSENT FOR PARTICIPANTS

OF INVESTIGATIVE PROJECTS

Title of Project: An investigation of accounting wealth changes using two and three-dimensional graphics.

Investigators: Richard B. Dull, Robert M. Brown (Faculty Advisor), Tarun K. Sen (Faculty Advisor)

I. Purpose of this Research/Project
This study examines the differences in decisions that are made when complex accounting information is provided in alternate representation forms. The study will extend the use of three-dimensional visualizations into the area of accounting. There will be approximately 120 subjects participating in the study.

II. Procedures
You will be assigned (randomly) to one of three groups. Based on the group, you will receive a certain set of visual representations of accounting information. To allow for supporting evidence regarding the process of the task, you are asked to think aloud (verbally state what you are doing) throughout the process and this will be recorded (audio). You will be given five examples to help learn the procedure. After the learning exercise, you will be asked to use the next five representations to answer questions and predict future information. After the completion of the task, there will be three series of questions. The first series is about the task, the second concerns how you visualize certain information, and the third series consist of demographic data. Your participation in the project is expected to last approximately one hour and will be completed at the end of the session today. The research will take place in Pamplin 3008 (the Pamplin School of Business Behavioral Lab).

III. Risks
There are no known risks associated with this study.

IV. Benefits of this Project
While there are no guarantees of benefit to you due to your participation, each participant will have the opportunity to increase their understanding of a complex accounting topic through the use of visual representations. This study will also help move forward the adaptation of current technology in the field of accounting.
If you are interested in the results of the study, you may contact the investigator for the research results

V. Extent of Confidentiality

Your responses and results will be confidential (your identity will not be divulged). An index card listing your name, e-mail or phone number, and an identifying code (alphanumeric identifying the group you are in, and the sequence within that group) will be used by the investigators to verify participation and ensure the provisional compensation is paid to the correct parties. The e-mail or phone number will not be used for any purpose except for notification if you win the bonus drawing. Twelve months after the experiment is complete, these cards will be destroyed. At no time will the researchers release any specific information that may be traced to you to anyone other than individuals working on the project without your written consent.
As stated in item II above, there will be an audio recording of the session. The tapes will be under the supervision of the investigators and will not be used for any purpose outside of this research. They will not be stored with any other information that might link them to you as an individual. Additionally, they will be transcribed under the supervision of an investigator and will be destroyed after a complete transcription is made.

VI. Compensation
Your compensation for the study will be $6.00 per hour and will be paid at the end of the session. Additionally, each subject will be entered into a prize drawing based on the accuracy and speed of their responses. There will be two bonuses ($75 and $25) for each of the four groups of subjects. For the purpose of the bonus drawing, you will only be compared to others within your group. If your accuracy rate is in the top 25%, second 25%, third 25% or bottom 25%, you will receive four, three, two or one chance(s) in the drawing. Additionally, if you accuracy rate is in the top 50% of your group, you can get bonus chances for the drawing, based on how quickly you completed the task. The following grid shows precisely how many chances you may have to win.

		Number of entries for bonus prize				
		Speed Bonus (only for top 50% accuracy)				
	Speed->	Top 25%	2nd 25%	3rd 25%	Bottom 25%	
Accuracy	*Chances*	4	3	0	0	
Top 25%	4	8	7	4	4	
2nd 25%	3	7	6	3	3	
3rd 25%	2	2	2	2	2	
Bottom 25%	1	1	1	1	1	

The drawing for the bonus will occur at the end of the data collection period (expected to be prior to May 8, 1997). The winners will be notified by phone or e-mail. If you are a winner, your name may be released as being a winner to other participants, although no indication of your performance of the task will be disclosed.
In addition to the monetary compensation, each subject will receive a bonus of 1% of the course grade for the course from which they are recruited. An alternate method of earning the credit will be given for those choosing not to participate.

VII. Freedom to Withdraw
You are free to withdraw from a study at any time without penalty. If you choose to withdraw, you will be compensated for the amount of time you participated.
There may be circumstances under which the investigator may determine that you should not continue as a subject. If this happens, you will be compensated for the amount of time you participated.

VIII. Approval of Research
This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University, by the Department of Accounting.

IX. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities:

To answer the task questions as accurately and quickly as possible.
To answer the follow-up questions to the best of my ability.
To keep confidential any information about this experiment, until June 1, 1997.

X. Subject's Permission
I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.
If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

______________________________ ______________________________

Signature Date

Should I have any questions about this research or its conduct, I may contact:

Richard B. Dull (Investigator) Phone: 231-6591
Robert M. Brown / Tarun K. Sen (Advisors) Phone: 231-6591

EXHIBIT 10

VERBAL PARTICIPANT EXPERIMENT INSTRUCTIONS

You will be participating in an experiment to examine the affect of information presentation on decisions relating to complex accounting information. You will be recorded, it is an audio recording, during the experiment. Please think aloud during your decision making process. The experiment consists of five sections; first, you will have a training task – you will predict seven values for two companies. After each prediction, you will be given feedback about the prior answer. The second segment is the actual experiment. It is identical to the training task except there is no feedback of correct answers. You will then move into a section that asks a few questions about the experiment. Next, there is another section that includes four groups of 4 questions that is designed to measure visual vividness. Last, there are several demographic questions. At the end, you will be asked to click to save your answers. After you have saved your answers, you are finished, come back to my office and sign the sheet for your professor and receive your compensation.

Notes:

If you want, you can predict outside the range of the axes included in the visualization.

Place the cursor on the field when typing in your predictions.

CAREFULLY read each question. During the experiment, some questions are very similar to others, with only one word or number different. Unless you read carefully, you may miss the differences.

Read all instructions.

Remember to think aloud.

Are there any questions?

EXHIBIT 11

EXPERIMENTAL TRAINING/TASK QUESTIONS

1) What do you expect wealth to be at month 101?

2) What do you expect wealth to be at month 110?

3) What do you expect wealth to be at month 120?

4) What do you expect momentum to be at month 101?

5) What do you expect momentum to be at month 110?

6) What do you expect momentum to be at month 120?

7) What do you expect impulse to be at month 105?

EXHIBIT 12

OVERVIEW OF WEALTH, MOMENTUM AND IMPULSES

It is generally accepted that the wealth of a company is equal to the value of its assets less any liabilities. Traditionally, accountants describe the difference between wealth at two points in time as income for that period (assuming there are no dividends)

It has been suggested that if you can determine a function for wealth, then you can develop a function of the *rate* by which wealth changes (Note: this is a *rate* rather than the traditional view of an *amount* for a specific period). Additionally, a function can be determined that represents impulses that affect that rate (an example of impulse would be the addition of a salesperson; one would expect this impulse to increase the *momentum* of earnings and the rate of *wealth* accumulation.) Based on these concepts, one may be able to use impulses and momentum to assist the prediction of wealth.

(Note: in mathematical terms, the momentum function is the first derivative of the wealth function, while the impulse function is the second derivative of the wealth function)

Your task for this experiment, will be to look at certain visual representations of predetermined functions of wealth, momentum and impulse and predict future values.

EXHIBIT 12A

INTRODUCTION FOR TRAINING TASK

To help you understand the visual representations and the process of answering the questions, you will be given information for two companies. Each representation will contain information regarding the wealth, momentum and impulse functions for a specific company. You will be shown the first representation asked to predict wealth for three designated future periods, momentum for three periods, and impulse for one period. After each response, you will be given the actual response. After completion of the first company, the same process will be completed for the other example company. Note: Do not be frustrated if your answer does not exactly match the actual answer; just use each answer as a learning process for any future questions. The first two companies will be used to give you a “feel” for the representation type you will be using. It should help you understand what is expected for the remainder of the experiment.

EXHIBIT 12B

INTRODUCTION FOR ACTUAL EXPERIMENT TASK

Now you are moving to the actual experiment. The process is identical to the training exercise, except you will not be given the actual response. You will be given the representations for four companies and asked to predict wealth, momentum and impulse.

EXHIBIT 12C

NARRATIVE FOR SUBJECTS USING
THE 2-DIMENSIONAL REPRESENTATION

You are looking at a 2-dimensional graph of wealth, momentum and impulse. Note the thickness of the lines. Please use the center of the line thickness for determining and estimating values.

Notice the relationship among wealth, momentum and impulse. As impulse increases or decreases, momentum increases or decreases. If impulse is positive, momentum increases and there is a corresponding change in wealth. If impulse is negative, momentum decreases and wealth will decrease or grow at a slower rate.

EXHIBIT 12D

NARRATIVE FOR SUBJECTS USING THE 3-DIMENSIONAL STATIC REPRESENTATION

You are looking at a 3-dimensional representation of wealth, momentum and impulse. Wealth and momentum axes are labeled. Impulse is described by the color of the line plotted. The colors range from 1 to 255 (See color legend). Note the thickness of the line. Please use the center of the line thickness for determining and estimating values. Also, be aware that you are looking down at the representation, at an angle. This should be taken into consideration when determining and estimating values.

Notice the relationship among wealth, momentum and impulse. As impulse increases or decreases, momentum increases or decreases. If impulse is positive, momentum increases and there is a corresponding change in wealth. If impulse is negative, momentum decreases and wealth will decrease or grow at a slower rate.

EXHIBIT 12E

NARRATIVE FOR SUBJECTS USING THE
3-DIMENSIONAL ROTATABLE REPRESENTATION

You are looking at a 3-dimensional representation of wealth, momentum and impulse. Wealth and momentum axes are labeled. Impulse is described by the color of the line plotted. The colors range from 1 to 255 (See color legend). Note the thickness of the line. Please use the center of the line thickness for determining and estimating values. If you want, you may rotate the image to help understand the relationship among the data. To rotate, place the mouse pointer on the image and click with the left mouse button. The image rotates in the direction of the displayed triangle.

Notice the relationship among wealth, momentum and impulse. As impulse increases or decreases, momentum increases or decreases. If impulse is positive, momentum increases and there is a corresponding change in wealth. If impulse is negative, momentum decreases and wealth will decrease or grow at a slower rate.

EXHIBIT 13

SAS PROGRAM FOR MANOVA ANALYSIS (APPENDIX)

This program was written by Peter Ammermann, Statistical Consulting Center, Virginia Tech, Blacksburg, Virginia.

```
options ls=80 pageno=1 nodate pagesize=56;

   filename subs 'c:\SAS\dis_some.csv';
   data one;
   infile subs delimiter=",";

    input pr11 tp11 pr12 tp12 pr13 tp13 pr21 tp21 pr22 tp22 pr23 tp23
       pr31 tp31 pr32 tp32 pr33 tp33 pr41 tp41 pr42 tp42 pr43 tp43
       vviq vviqa sex comp math major rep_meth group subj;
    if vviq=-1 then vviq=.;
    lnsqer11=log(((pr11-8.92)/8.92)**2);
    lnsqer12=log(((pr12-5.81)/5.81)**2);
    lnsqer13=log(((pr13-5.50)/5.50)**2);
    lnsqer21=log(((pr21-94.45)/94.45)**2);
    lnsqer22=log(((pr22-102.77)/102.77)**2);
    lnsqer23=log(((pr23-205.71)/205.71)**2);
    lnsqer31=log(((pr31-9.22)/9.22)**2);
    lnsqer32=log(((pr32-18.17)/18.17)**2);
    lnsqer33=log(((pr33-42.08)/42.08)**2);
    lnsqer41=log(((pr41-421.68)/421.68)**2);
    lnsqer42=log(((pr42-593.59)/593.59)**2);
    lnsqer43=log(((pr43-827.03)/827.03)**2);
    if group in (1,3,5) then order=0;
       else order=1;
  cards;
  ;
  proc glm data=one;
    class rep_meth order;
    model lnsqer11 lnsqer12 lnsqer13 lnsqer21 lnsqer22 lnsqer23
       lnsqer31 lnsqer32 lnsqer33 lnsqer41 lnsqer42 lnsqer43
       = rep_meth / nouni;
    contrast 'Rep1 vs. Rep2' rep_meth 1 -1 0;
    contrast 'Rep1 vs. Rep3' rep_meth 1 0 -1;
```

```
   contrast 'Rep2 vs. Rep3' rep_meth 0 1 -1;
   manova h=rep_meth / printe;
   lsmeans rep_meth;
 run;
quit;
```

VITA

RICHARD B. DULL

Education:

Doctor of Philosophy in Business
[Accounting Information Systems]
Virginia Tech, Blacksburg, VA — August 1997

Master of Business Administration [Accounting]
University of North Carolina at Greensboro — December 1982

Bachelor of Business Administration [Accounting]
Bachelor of Science [Computer Applications]
Harding University, Searcy, AR — May 1980

Experience:

Graduate Teaching Assistant (while pursuing Ph.D.)
Virginia Tech, Blacksburg, VA — 1994-1997

Visiting Lecturer/Instructor
High Point University, High Point, NC — PT 1987-1989/FT 1989-1994

President/Partner
Intelligent Technologies, Inc., Greensboro, NC — 1986-1994
[Known as Weathersby Dull Bostian & Waynick, CPAs from 1986 to early 1993]

Accountant/Senior Consultant
McGladrey Hendrickson & Pullen, CPAs, Greensboro, NC — 1983-1986

Senior Programmer
Cone Mills Corporation, Greensboro, NC — 1980-1982

Research Interests:

- Visual representations of accounting information for decision-making
- Using systems to increase individual and organizational effectiveness
- Success of system implementations