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# A Comparative Analysis of Dynamic Representations of a Firm's Operating Activities

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## ABSTRACT

Information is often multidimensional, dynamic and difficult to communicate using traditional representations such as verbal descriptions or even graphics. With the development of advanced visualization technology, it is possible to create more effective representations. Taking a distributed cognition perspective and integrating several theories of visualization, I have formulated a theoretical model. The resulting model is being used to examine the advantages of animated visualizations in representing dynamic information and in facilitating decision-making.

## Keywords

Visualization, animation, representation, decision-making, accounting information systems

## INTRODUCTION

Information is often complex and difficult to communicate using traditional representations such as verbal descriptions or even pictures. With the development of advanced visualization technology, it may be possible to create effective ways to represent complex data so as to facilitate decision-making. Animations have the potential to convey dynamic and multidimensional information (Friedhoff and Peercy, 2000; Tversky, Morrison and Betrancourt, 2002). Taking a distributed cognition perspective and integrating cognitive fit theory with several theories of visual perception, I formulated a theoretical framework. The resulting model was used to examine the question "Can animated visualizations improve multidimensional and dynamic-information-based decision-making?" Because accounting information is multidimensional and dynamic, and because decision makers often find it difficult to discover relationships hidden in this complex information, I took accounting as the environment within which to explore the research question. In particular, I am investigating whether animated visualizations can enhance the understanding of multidimensional accounting information and further improve decision making when compared with traditional financial statements or graphs.

## THEORETICAL BACKGROUND

A basic principle of distributed cognition is that a cognitive task includes both internal and external representations, which together contain the abstract structure of the task (Zhang and Norman, 1994). In a study using the Tower of Hanoi problem, in exploring the nature of external representations, Zhang and Norman determined that they 1) can serve as memory aids, 2) provide information that can be perceived and used directly without being interpreted and formulated explicitly, 3) anchor and structure cognitive behavior, and 4) change the nature of a task. According to Hutchins, the nature of the external representations available greatly influences an individual's cognitive performance (Hutchins, 1995). So in order to perform a cognitive task, such as making a business judgment or decision, people need to process information distributed across the internal mind and the external environment.

Contemporary cognitive scientists argue that the internal representations stored in our minds cause and explain much of behavior. Dual coding theory suggests that memory consists of two separate and distinct mental representation systems—verbal and nonverbal (Paivio, 1986). Information is much easier to retain and retrieve because of the availability of two representation systems, and recalling information in the visual system is faster than recalling information in the verbal system because the visual system accesses information through synchronously, as opposed to the sequential access of the verbal system. Further, people process and recall pictures more fully than words and sentence.

External representations include the knowledge and structures in the environment. They are not simply inputs to the internal mind. Recent studies have found that external representations can significantly change the ease and even the nature of many

cognitive tasks. Although external representations exist in many forms, one important class of external representations that make us smart is graphical inventions of all sorts (Card, Mackinlay and Shneiderman, 1999). Tables and graphs are both used to represent large data sets. Many studies have explored the features of these two representations and the conditions under which each is superior. A series of experiments summarized by Benbasat *et al.* concluded that graphical presentation was more useful in searches for optimal solutions, but that tables were more useful in tasks that required determining exact numbers (Benbasat, Dexter and Todd, 1986). In the study that is most closely related to the current research, Volmer compared graphical presentations of the financial ratios of the firm with numerical financial information, and concluded that graphical information not only saved time, but was also considered important to providing clear insights into the financial position of the firm, thus improving communication (Volmer, 1992). With the emerging visualization technology rapidly grows, animated graphics become ubiquitous. There is a general belief that animations not only improve users' understanding, but also make interfaces easier and more enjoyable to use. This belief has been tested in many studies, although the results have not produced a consensus. In a review, Tversky, *et al.* argued that empirical studies have not provided strong evidence that animated graphics out-perform static graphics, but they are particularly promising in conveying real-time changes and temporal-spatial reorientations due to people's natural cognitive correspondences based on the congruence principle (Tversky, Morrison and Betrancourt, 2002). Prior research suggested that animations can enhance comprehension, problem-solving, learning and presentation persuasiveness (Morrison and Vogel, 1998; Rieber, Boyce and Assad, 1990; Lightner, 2001). Movement and interactivity are two important attributes of animations which affect the early preconscious stages of visual processing, and further facilitate the effective use of visualization by increasing the amount of preconscious processing (Stanovich and West, 2000; Friedhoff and Peercy, 2000). Since our visualization is for use with data that have a strong temporal character, and in an environment where there will be repeated use and learning, we have reason to anticipate that animation will be useful.

Whatever external representations we create have to link to the internal representations that people produce. Scaife and Rogers identified three characteristics that can be used to explain the connection between internal and external representations: computational offloading, re-representation and graphical constraining (Scaife and Rogers, 1996). Visualization can substitute preconscious visual competencies and machine computation for conscious thinking (Friedhoff and Peercy, 2000). The term preconscious refers to the hardwired highly parallel processes that handle the initial stages of the analysis of retinal patterns. Such processing is fast, automatic, and indefatigable, so it carries less cognitive load than conscious processing. Color, size, contrast, and movement are properties that preconscious visual processing (Friedhoff and Peercy, 2000). Similarly, a long history dual-processing theory argues that there are two systems involved in human reasoning. System 1 is associative, holistic, heuristic, quick, implicit, and intuitive, whereas System 2 is rule-based, analytic, slow, explicit, and controlled. Stanovich and West argued that we had little awareness of System 1's existence, although it had a significant effect on our cognition processes and reactions (Stanovich and West, 2000). Cognitive fit theory argues that the effectiveness of problem solving is a function of the relationship between the problem solving task and the representation (Vessey, 1991). To be effective, representations must be driven by the characteristics of the tasks to be supported. In a word, the prior literature provides a basis for optimism that an animated graphic representation will be useful given our objective of developing an understanding of the dynamics of an organization through time.

## RESEARCH FRAMEWORK

According to the literature reviewed above, animations as external representations have the potential to directly invoke perceptual operations and provide information that can be directly perceived and used without being interpreted and formulated cognitively. Perceptual views and dual-processing theory also suggest that the effective use of visualization can be facilitated by increasing the amount of preconscious processing involved in System 1 to reduce cognitive loading. Cognitive fit theory suggests that more effective and efficient problem solving results when the problem representation matches the task to be accomplished (Vessey, 1991). Zhang found that if affordances are consistent with task structure, they can make tasks easier (Zhang and Norman, 1994). In holistic processing, the whole is perceived directly rather than as a consequence of separate perceptual analyses of its constituent elements. In contrast, analytic processing involves decomposition of the whole into separable properties, with perception and processing following in a feature-by-feature. Holistic processing tends to be more efficient and effective because separate properties or dimensions are considered together. Graphical representations were found particularly useful for holistic processing involved tasks, namely "holistic tasks" (Umanath and Vessey, 1994; Dennis and Carte, 1998). All the evidence above leads me to the following hypotheses:

**Hypothesis 1.1:** People using animated visualizations perceive holistic tasks easier than those using static representations.

**Hypothesis 1.2:** There is no difference in perceived ease of non-holistic tasks between animated visualizations and static representations.

**Hypothesis 2.1:** For holistic tasks, using animated visualizations increases the speed of performance compared with using static representations.

**Hypothesis 2.2:** There is no difference in speed on non-holistic tasks between animated visualizations and static representations.

**Hypothesis 3.1:** For holistic tasks, animated visualizations increase the accuracy of task performance compared with static representations.

**Hypothesis 3.2:** There is no difference in accuracy on non-holistic tasks between animated visualizations and static representations.

## THE VISUALIZATION

The Cycle Model is a useful environment within which to test the theoretical framework. The simplest version of the cycle model is comprised of three interacting cycles. In the leftmost cycle the firm acquires raw materials from its suppliers. The center cycle is the transformation cycle, where value is added to the raw materials through the manufacturing processes to create finished goods (or services). The right cycle is the output cycle which represents the sale of the finished goods to the customers. The dark grey path represents the movement of material and the light grey path represents the flow of cash.

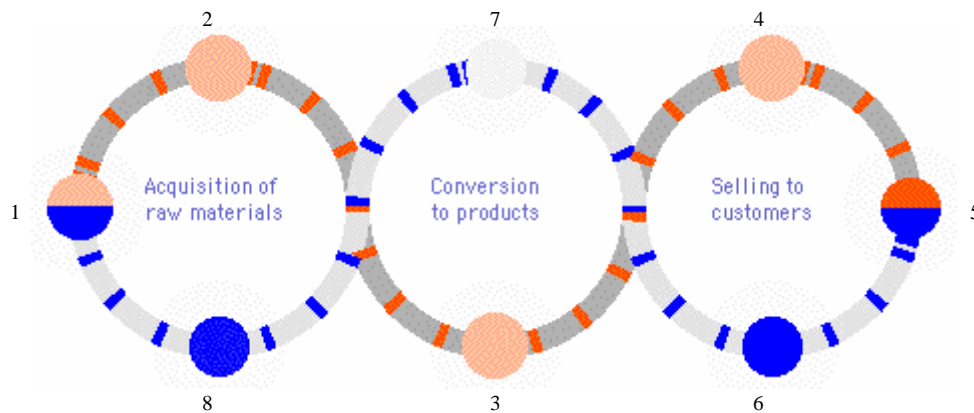


Figure 1. The Cycle Model

There are eight critical transition moments along the two paths. At moment 1, the firm issues credit purchase orders to its suppliers. The next transition point along that path (moment 2) represents the receipt of raw materials. These materials are transferred to the transformation cycle at moment 3. In the transformation cycle, labor is applied to turn the raw materials into finished goods which are available for sale at moment 4. At moment 5, a customer agrees to purchase the goods, which are delivered at moment 6. Moving in the other direction, cash is received from customers at moment 7. The cash flow moved back through the cycles to moment 8, where it is used to pay suppliers. These flows represent the overall operating cycle. The size of moments represents the capacity of that part of the enterprise. The moment's brightness represents how much of the capacity is currently in use. The speed of connections between moments varies based on ratios representing the time it takes for the system to make the necessary transformation. Specifically, the inventory turnover ratio is represented by the speed of flow on the path from moments 1 to 5; the accounts receivable turnover ratio by the speed of cash flow between moments 5 and 6; and the direct operating flow from moment 2 to moment 8. This stylized representation, the operating cycle, represents the day-to-day operations of the firm. For a firm to be able to operate, however, requires capital investments in property, plant, and equipment and the funding to make those investments. The simple model shown assumes an existing firm with adequate resources for its current level of operations. The possibility of changing those levels of resources requires appending two additional cycles to the model, an investing cycle and a financing cycle.

The overall activities of the firm represented in this model should seem somewhat familiar to financial statement users since it conforms roughly to the structure of the cash flow statement and its labeled sections. This stylized representation illustrates most of the flows presented in the financial information currently produced by firms.

## RESEARCH DESIGN

Visualization research often uses lab experiments to study differences among representations. My design takes that approach. For holistic tasks, decision makers must evaluate the situation as a whole and derive an intuitive feeling about the tasks. Specifically, multiattribute judgment tasks belong to this type (Umanath and Vessey, 1994), so a holistic task requiring subjects to make a high level assessment of a firm's performance will be used. Subjects will assess ten firms' operating activities over a five to ten years' period. For the dependent variables, I have adopted two widely used objective performance measures—time and accuracy. Perceived ease of use is also assessed using instruments from prior research. Type of representation is the principal independent variable. Representations were of three types—tables, graphs and animations (the Cycle Model). For tables, the most important variables were selected from Comparative Statements of Cash Flow and presented using the same format as general financial reports. Graphical representations were based on conventional financial market practice: financial statement balances as bar graphs and financial ratios as line graphs. All three representations present the same information.

## EXPECTED CONTRIBUTION AND RESEARCH PLAN

This study integrates and tests several theories to better understand how animated visualizations affect decision making in a business context. It empirically compares animations with static graphs and with tables on a complex decision-making task involving multidimensional and dynamic information. Several pilot studies will be conducted to validate the instrument and research design before the formal experiment. Statistical analysis will be conducted to analyze the results.

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