Visual Artefacts and Decision-Making Quality in Information Systems Development Projects

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Abstract: Visualization of data provides positive cognitive and operational functions for decision makers in information systems development environments. In this research-in-progress paper we discuss both distortive and nondistortive visual artefacts and seek to determine the impact these two types of artefact have on the relationship between decision inputs and decision quality. Given the cognitive limitations of the decision makers, incomplete information regarding the potential decision quality and the time limitations on the decision-making process, we use the theory of bounded rationality to guide our research. We distinguish between distortive (where data are altered for display) and non-distortive (where data are not altered for display) visual artefacts, and explore which of these is the optimum choice for decision makers in ISD environments.

Keywords: Decision making, Decision makers, Information systems development, Visualization, Bounded rationality

1 INTRODUCTION

Despite advances in decision theories and technologies to support decision makers in information systems development (ISD) environments, decision making continues to pose challenges for the software development community (Keil, Mann et al. 2000; Montealegre and Keil 2000; Conboy and Fitzgerald 2010; Coyle 2011; Moe, Aurum et al. 2012). With an overwhelming availability of information and an increasing complexity of decision-making scenarios, decision makers are often faced with the conundrum of planning for ISD projects with imperfect information (Noppen 2008) and limited time (Park, Im et al. 2008; Cao, Mohan et al. 2009). In an attempt to address these problems, managers often enlist the support of decision support tools and project management software which helps aggregate and present pertinent data to the decision maker.

Data visualization is a potential way to counteract cognitive information overload by using visual artefacts to communicate complex information to decision makers. Visual representations have the capacity to provide an effective format for displaying and communicating information to support decision making. A good diagram can convey instantly a relationship or pattern that would otherwise require a laborious, time consuming and easily forgotten explanation (Platts 2004; Killen and Kjaer 2012). Most visual displays are static by nature, although there are attempts in some displays to incorporate representations of change and dynamism (Warglien 2010). However, a review of the literature on data visualization shows that little is currently available to guide managers in applying visualization techniques to assist them in planning ISD projects (Platts 2004).
2 Visual Representation

Popularized by the Minnesota experiment (Dickson 1977), visual representation usually refers to different means of expressing and representing information in understandable forms for decision makers to make informed decisions. Commonly used formats such as text (Kuechler 2006), graphs and charts (Shneiderman 1977; Kumar 2004; Miranda 2010), maps (DeLine 2010), and visual metaphors (Breciani 2009; Kernbach 2010) can provide aggregated data to the decision maker in an easily understandable format. Given that eighty five percent of an organization’s information can be stored as unstructured data (Robb 2004), decision makers often suffer from cognitive overload when they attempt to make decisions (Nissen and Sengupta 2006). Platts and Hua Tan (Platts 2004) identified a number of positive cognitive and operational functions of visualization for managers (Table 1).

Table 1 Visualization Functions (Adapted from (Platts 2004))

<table>
<thead>
<tr>
<th>Cognitive Functions</th>
<th>Description</th>
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<tbody>
<tr>
<td>Focuses attention</td>
<td>Allows managers to identify the areas of interest</td>
</tr>
<tr>
<td>Triggers memory</td>
<td>Allows managers to make connections among past events</td>
</tr>
<tr>
<td>Shares thinking</td>
<td>Enables managers to share their thinking with colleagues</td>
</tr>
<tr>
<td>Stimulates thinking</td>
<td>Provides an invitation to view a situation in a way that often stimulates fresh thinking</td>
</tr>
<tr>
<td>Bridges missing information</td>
<td>Exploits the human visual system to extract information from incomplete data</td>
</tr>
<tr>
<td>Challenges self-imposed constraint</td>
<td>Enables managers to look at a problem in a new way</td>
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<table>
<thead>
<tr>
<th>Operational Functions</th>
<th>Description</th>
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<tbody>
<tr>
<td>Identifies structure, trends, and relationships</td>
<td>Identifies structure, patterns, trends, anomalies, and relationships in data</td>
</tr>
<tr>
<td>Displays multivariate performance Highlights key factors</td>
<td>Enables managers to analyze complex performance allows managers to specify explicitly their views on the importance weighting of variables</td>
</tr>
<tr>
<td>Provides an overview of complex datasets</td>
<td>Provides a picture of the problem that is relatively easily examined, explored, and if appropriate, changed. Managers often have difficulty perceiving the dependencies among choices, uncertainties, and outcomes</td>
</tr>
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Informational content can have different underlying structures and methods of representation. Gershon et al. (1998) describe visualization as the process of “transforming data, information, and knowledge into visual form making use of humans’ natural visual capabilities”, and state that visualization “provides an interface between two powerful information processing systems - the human mind and the modern computer.” Visualization presents information to users. The persuasive impact of particular visualizations may influence a user’s impression of the system (Morrison and Vogel 1998), and affects the usability of the information.

Leung and Apperley (Leung and Apperley 1994) argue that the presentation of information can be approached in terms of informational content presentation and also in terms of the structure of that content. Accessing information using information systems with poorly designed presentation outputs can be less than satisfying, cumbersome, and can involve significant effort, at times involving a higher cognitive load in terms of remembering visited data as well as navigational aspects, and be suboptimal for task-based behaviour. For example, it is possible that the entirety of a textual document could be displayed on a monitor screen by automatically reducing the size of the text so that all would fit (Leung and Apperley 1994), but such a presentation may reduce the usability of the document. In a variety of presentation formats the user is given the freedom to control the quantity of information displayed at a given time by using such directly manipulative measures as scrolling, hyperlinks, and zooming. Such actions tend to be typical for interactions where interfaces and displayed data and information are not structurally altered. For example, web users searching an online store for a consumer good may find the results of such a search displayed in an itemized table of matching
alternatives, each described by attributes: such a table may have a large amount of data, and in such cases is most often presented on-screen with the user requiring scrolling to see its entirety. Such presentation formats, where data are not altered or transformed for display are termed non-distortive (Leung and Apperley 1994; Yang 2003). Leung and Apperley (Leung and Apperley 1994) outline non-distortion oriented abstraction of objects, whereby a portion or aggregate of the overall quantity of information is presented on a given spatially restricted display area, and user-controlled scrolling or paging allows the output of other parts of the information. They found that although non-distortion oriented techniques may be adequate for small text-based applications, their main limitation is that generally they “do not provide adequate context for the user to support navigation of large-scale information spaces”. Indeed as the informational space and the volume of information increases, it becomes more difficult to use the data without some degree of assistance, data aggregation, filtering, or restructuring.

On the other hand, in efforts to maximize the representation of large amounts of data or objects, distortion-oriented techniques allow the user to examine a local area in some detail on a section of the screen, yet also allow the presentation of a global view of the space to offer an overall framework to assist navigation. Distortive presentation of data and graphical objects involves transformations of the data and screen components to be better represented, more manageable, or to ‘fit’ aggregation or data-selective needs. One way of maximizing the display of informational content is to improve the efficiency by which its underlying structure is represented (Kamba, Elson et al. 1996). This approach was taken by Card, Robertson and Mackinlay (Robertson, Card et al. 1993) (1993) using an ‘Information Visualizer’ tool to magnify certain portions of available information. The main purpose of these techniques is to allow the user to examine a local area in detail on a section of a screen, and at the same time, to present a global view of the space to provide an overall context to facilitate navigation and understanding of context. Other approaches such as ‘Hyperbolic Geometry’ (Lamping and Rao 1996) and ‘Cone Tree’ (Robertson and Mackinlay 1993) attempt to maximize value by presenting distorted displayed representations of the information. ‘Cone Tree’ represents on-screen data hierarchies in 3D cone-shaped graphics, whereas ‘Hyperbolic Geometry’ displays a focused point within a data hierarchy in a large bounded area of on-screen space, and its context in a smaller bounded area (Kamba, Elson et al. 1996). Such distortive informational representation techniques have been used in scenarios where significant quantities of information need to be visibly available on-screen at the same time (Mackinley, Robertson et al. 1991; Kumar, Plaisant et al. 1997). However, distortive approaches significantly alter the presentational display of data and interface objects such as graphical symbols and images, and introduce specialized or unique interaction techniques particular to the approach. For example, cone tree and hyperbolic presentations can involve the user employing interaction techniques such as 3D scrolling in conjunction with zooming and other techniques that may be foreign and unnatural when compared with traditional interaction elements such as button-presses, dialog boxes, and scroll arrows such as those found on 2D screens. This introduces a learning effort for the user in the context of new or novel interaction methods, and the introduction of an ‘unnaturalness’ that may adversely affect usability or acceptance. Leung and Apperley also outline other distortion-oriented display techniques such as ‘Bifocal Forms’, and ‘Fisheye’ views, whilst others describe techniques such as ‘Document Lens’ (Shneiderman 1998) and ‘Treemap’ (Asahi, Turo et al. 1995) for data representation and visualization. Although various descriptions of fisheye views appear in the literature (Mitta 1990; Leung and Apperley 1994; Yang 2003), all apply mathematical transformations to data objects that are to be displayed on-screen, which address usability by allowing the user to see portions of the display at magnified visibility. Such schemas distort the information insofar as reducing, reformattting, or aggregating the data displayed: images can be reduced to thumbnails, text can be truncated in initial views, and tabulated data can be filtered, summarized, or structured for display in ways that can alter the rationale behind the table’s construction.

On the other hand, non-distortive display techniques such as scrolling, zooming or other direct manipulation techniques map generically to a physical and usage naturalness. For example, navigating a web page through vertical scrolling, or clicking buttons to perform actions, are everyday interaction techniques that are ubiquitous and well-understood by users of computing system. In scenarios of use where regular user interaction with a software system is essential, most software-based elements of modern computer system interfaces contain visual graphical representations of real
world objects together with metaphors and other symbols, alongside visual elements such as buttons and menus to enable user interaction (Preece 1994).

Kuechler and Vaishnavi (2006) found that augmenting text-based IS to elicit and saliently present information will enhance decision-making outcomes for rapid, ad hoc decisions. Kumar and Benbasat (2004) found that 3D graphs consistently outperform 2D graphs. Lim and Benbasat (2002) show that multimedia facilitates the retention and subsequent recall of explanatory information but not of descriptive information. Zhu and Watts (2010) suggest that visualization can enable superior outcomes when they are designed to support the interaction between cognitive fit and working memory. Another stream of research is where decision making is particular to a certain situation. For example, Roy and Lerch (1996) found that graphs were better performance indicators than text or tabular information for base-rate decisions, i.e. taking into account prior beliefs when new evidence is obtained. Despite a general agreement that visualization of data will affect decision outcomes, research to date has not been conclusive. Previous research on visualization modes often provides conflicting findings. For example, Stanfey and Hastie (1998) find that text and stories provided the most accurate results. Dolan et al. (2012) conducted an experiment of five data presentation formats and found no discernible difference among formats for providing comparative effectiveness information.

Given these conflicting results and the lack of guidance concerning the use of visual artefacts in ISD in particular, this study seeks to answer the following research questions; firstly, do visual representations moderate the effect of decision inputs on ISD decision making quality? And secondly, how do visual representations of data moderate the effect of decision inputs on decision making quality?

3 DECISION QUALITY

The decision support systems literature uses the terms ‘decision accuracy’ and ‘decision quality’ somewhat interchangeably, usually describing the same thing. In this regard decision quality is understood as “the deviation of a particular solution from the solution that would be provided by a normative strategy, such as expected value maximization or utility maximization” (Todd and Benbasat 1992), and is essentially equivalent to decision accuracy. Elsewhere, decision quality is taken as a superset of accuracy (Moldafsky and Kwon 1994), and in addition to the accuracy of the decision can encompass more perceptual aspects of the decision outcome and process from the decision maker’s perspective, such as perceptions of confidence in the decision, or subjective satisfaction with the decision process or outcome. The effort expended in decision making is a core antecedent of decision quality (Todd and Benbasat 1992). Studies indicate that effort is paramount and central in its influence on decision behaviour (Todd and Benbasat 1992): decision-makers tend to try to find a solution to tasks with minimal effort yet desire accurate decisions. Studies have shown that there is an effort-accuracy trade-off in achieving quality decisions: where less effort is employed in decision making, the decision is of a lower quality (Moldafsky and Kwon 1994; Garrity, Glassberg et al. 2005). Impacted by personal traits and abilities such as self-efficacy or bounded rationality, the trade-off between accuracy and effort is also influenced by task complexity, informational representation, and decision aids or support mechanisms (Payne 1982). Because of this trade-off, decision makers frequently choose options that are satisfactory yet may be suboptimal (Haubl and Trifts 2000). This is common in instances where the complexity of the decision process or environment is high, when alternatives are numerous or difficult to compare (Haubl and Trifts 2000; Garrity, Glassberg et al. 2005). It follows that if decision support mechanisms can lower the effort required yet maintain decision quality, decision making becomes easier. With respect to individuals’ willingness or propensity to “settle for imperfect accuracy in their decisions, in return for a reduction in effort” (Garrity, Glassberg et al. 2005), the concept of decision satisficing in this context is consistent with bounded rationality and cognitive abilities. Where decision making has a time relevance or a time criticality, for example, allocating resources to a team with an impending deadline, satisficing may be exacerbated. In such scenarios searching “for the right information and making quick, accurate decisions within time-pressured settings is often non-trivial” (Aminilari and Pakath 2005), with decision time pressures increasing the likelihood of decisional errors and reducing decision quality.
A central component of decision quality is decision maker confidence. The higher the amount of confidence one has in a decision, the higher is the strength of belief and trust in the decision (Adidamm 2000). There is a distinction between post-decision confidence in a decision taken (for example, confidence in having chosen a particular set of functionality to build into a software product), and pre-decision confidence in one’s ability to make a quality decision prior to embarking on the decision task. The latter can sometimes be independent of the decision task and its definition, and is more related to user characteristics, personal traits, personality, self-efficacy, and decision-making experience. Studies have shown that pre-decision confidence can affect decision quality, positively in terms of decision maker experience of selecting and confidently using more cognitively effortful decision approaches, yet negatively where over-confidence can result in the decision maker either not applying appropriate approaches for the problem at hand, and instead applying inferior choices (Su and Lin 1998; Bingi 2001), where intransigence or inexperience results in an inability to recognize an inferior decision outcome (Su and Lin 1998), or where unnecessary or unrecognized risk is taken in decision making (Kasper 1996). Over-confidence in a decision maker’s ability to reach a quality decision prior to making that decision can affect the amount of effort the decision maker commits to the decision process (Adidamm 2000; Bingi 2001). Post-choice decision satisfaction is also an important component of decision quality: indeed, overall satisfaction with an information system is an antecedent of acceptance and usage of that system (DeLone and McLean 2003). Garrity et al. (2005) argue that overall satisfaction encompasses satisfaction with task- and decision support, and showed that these are highly associated. Further, using a multi-attribute preferential choice task involving a non-distortive tabulated data visualization, they showed that satisfaction has positive impacts on decision quality.

4 DECISION INPUTS

Information load and time constraints are often exacerbated in ISD, particularly in newer agile contexts. Agile development requires the team to adopt a collaborative, but speedy decision-making process frequent software releases necessitates quality decision making (Cockburn and Highsmith 2001). One big issue is estimates, because poor estimates have consequences for resourcing, prioritization, and capacity planning (Henry, McCray et al. 2007). For this study, our decision inputs are the team estimates, which take into account the type of task, and the time and resources required to complete it. Our research model (Figure 1) reflects this view where decision inputs and decision quality are discrete variables and visual artefact is a categorical variable.

5 CONCLUSION AND FUTURE WORK

In current ISD environments, ISD teams are required to make regular decisions with incomplete information regarding the outcomes of those decisions. They are often required to make these decisions within a limited timeframe (particularly in environments using iterative or agile methods). Given the large amount of data available and the cognitive limitations of decision makers, decision
makers often resort to satisficing rather than maximizing their choices. Visual artefacts have shown great promise in aiding decision makers by presenting data in an easily recognizable format. We are currently developing a set of distortive and non-distortive visual artefacts which will be used in a large-scale case study to explore their impact on decision quality for information systems development estimating and planning. We hope to quantify the impact of both the distortive and non-distortive artefacts and further to this we will then explore, using Platts and Hau’s framework, how these visual artefacts improve decision quality. This will provide us with insights into which artefacts produce the best results for ISD teams and how they do this.

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References


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