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Presenting the unpresentable: how to display data for decision making

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Abstract

A concern with computer systems is how best to present onscreen data. This can be particularly problematic for large quantities of data and in contexts of organisational and managerial decision making. Another concern is how users can interact with, navigate and filter displayed data. These issues are encompassed by the usability of the user interface to information systems. With the ubiquity of computing resources in the 21st century, data are gathered by organisations in vast quantities, stored and queried for organisational ends. However there are questions regarding the usability of such data, and their value to managers faced with decisions at operational, tactical and strategic levels. Solutions to increase the usability of graphical user interfaces, to the display of information on computer screens, and to address the increased effort associated with the usage of large amounts of data need to be addressed. Where an information system uses and displays large amounts of data on computer screens, such as spreadsheet applications or database- or web-based searches, there can be compromises in ease of use, usefulness, and perceptions towards the 'friendliness' of the data as workable and

appropriate for certain tasks. Sometimes it can be better to display data in aggregate form, in tables or as charts, and with drill-down or exploratory opportunities for various purposes; on the other hand for some decision making scenarios it can be better to present and visualise data in their entirety, and can sometimes involve various kinds of visualisation aids and display formats. Indeed, in decision-making usage scenarios usability- or user performance shortcomings of various kinds of informational display formats may be influenced by the type and usage of such formats and display approaches, and compensated by software functionality that provides decision task support. If such shortcomings can be addressed and compensated, perhaps through support systems targeting improved efficacy or usability in terms of the usage of information systems for decision-making tasks, or through approaches to matching display formats with task, then the usefulness and user perceptions towards the suitability and usability of data for critical or important organisational and managerial function may be positively impacted. This paper discusses various approaches to data display and presentation on information systems, and presents a discussion on the suitability of presentation type for certain managerial decision-making tasks.

1. Introduction

One of the common problems associated with large computer-based information systems is the ‘relatively small window through which an information space can be viewed’ (Leung and Apperley, 1994). Indeed ‘what’ information is displayed as output on the display screens of computing devices such as PCs, notebook computers or mobile systems is distinct from ‘how’ that information is displayed. Leung and Apperley (1994) argue that the presentation of information on output devices such as computer screens can be approached from a user interface perspective in terms of informational content presentation and also in terms of the structure of that content. However, devices with small output screens, such as mobile phones and personal digital assistants (PDAs), are restricted in the quantity of data that can be displayed on screen at a given time, and also on the means by which such data can be presented effectively (Kamba, Elson, Harpold, Stamper and Sukaviriya, 1996). With access to data becoming more and more pervasive using a variety of device and in a variety of circumstances, there is a need to understand the best way of presenting data and information to end users. In particular, this paper focuses on potential approaches to data presentation in managerial decision contexts.

2. Theory

With many output devices such as computer monitors, there are situations where the size restrictions of the device curtail the amount or quality of information that can be made available to a user at any given time (Graham, Kennedy and Benyon, 2000). For example, a user may have to scroll a page of text on screen to be able to view all of that text. With non-distortive output, such a textual document would not be compromised for display by automatically reducing the size of the text so that all would fit on a single screen (Leung and Apperley, 1994). Rather, the user is given the freedom to control the quantity of information displayed at a given time by using such measures as scrolling, hyperlinks, and zooming. Leung and Apperley (1994) outline non-distortion oriented abstraction of objects, whereby a portion 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. Whilst textual nongraphical forms of data may lend themselves more pliably towards representation using non-distortive techniques such as text scrolling, data that is inherently graphical (such as drawings, icons and other symbols) have implicit spatial relationships with other objects that may pose limitations on their representation (Benderson and Hollan, 1994).

Leung and Apperley (1994) 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’. On the other hand, in efforts to maximize the available screen area where there may be spatial or information-density problems with 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. However, applying distortive representation techniques such as the shrinking of some kinds of graphics so that more data is represented on screen may lead to usability issues (Kamba et al., 1996). The available screen area for output of information and visual representation of software-based interface components such as graphical elements affects not only the informational content but also the structure of that content (Kamba et al., 1996).

An approach to maximizing the display of informational content is to improve the efficiency by which its underlying structure is represented on-screen. This approach was taken by Card et al. (Card, Robertson and Mackinlay, 1991) using an ‘Information Visualiser’ tool to magnify certain portions of a display screen. The application of distortion techniques can be attributed to the availability of low-cost and high-performance graphics capabilities (Leung and Apperley, 1994). The main purpose of these techniques is to allow the interface’s user to examine a local area in detail on a section of the display 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, Rao and Piroli, 1995) and ‘Cone Tree’ (Robertson and Mackinlay, 1993) also attempt to maximize the available screen space 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 et al., 1996). Such distortive informational representation techniques have been used in displays where significant quantities of information needs to be visibly available on-screen at the same time (Kumar, Plaisant and Shneiderman, 1997; Mackinley, Robertson and Card, 1991).

Other distortive methods of information display have also been applied to output screen displays to maximise the available viewing area: one example is ‘Perspective Wall’ (Mackinley et al., 1991), which ‘displays relations between different nodes within the same document on two adjacent planes (‘walls’), with semantic or structural differences between the nodes represented by the relative positions of the nodes on these walls’ in an effort to smoothly integrate detailed and contextual views of data to assist in the visualisation of linear information. Gershon, Eick and Card (1998) describe visualisation as the process of ‘transforming data, information, and knowledge into visual form making use of humans’ natural visual capabilities", and state that visualisation ‘provides an interface between two powerful information processing systems - the human mind and the modern computer.’ In essence the perspective wall technique applies mathematical algorithms to the data so that a three-dimensional rectangular magnified area appears centrally on the user’s screen (Brachtl, Slajs and Slavik, 2001), with linearly connected data represented as adjacent out-of-focus and size-reduced rectangles.

Leung and Apperley (1994) also outline other distortion-oriented display techniques such as 'Bifocal Forms', and 'Fisheye' views, whilst other authors describe techniques such as 'Document Lens' (Shneiderman, Byrd and Croft, 1998) and

'Treemap' (Asahi, Turo and Shneiderman, 1995) for data representation and visualisation. Although various descriptions of fisheye views appear in the literature (Mitta, 1990; Turetken and Sharda, 2004; Yang, Chen and Hong, 2003), all apply mathematical transformations to data objects that are to be displayed on-screen, which allow the user to see portions of the display at magnified visibility.

Common to approaches to maximise the available and usable screen area is a reliance on the application of appropriate graphical elements (in the form of abstract metaphors, icons, and symbols) together with on-screen data in textual form; combined with well-defined input and output mechanisms appropriately designed to enable user interaction with the interface. Indeed, metaphorical representation of meaningful information is an essential element of user interfaces for systems displayed on various screen sizes (Marcus, 1993), whether it is manifested as a flashing vertical line on a command-line interface to indicate readiness to accept textual input from the user, or as a symbolic icon representing an executable software application on-screen that can be activated by clicks from the user's mouse.

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, Rogers, Sharp, Benyon, Holland and Carey, 1994).

2.1 The elements of display

Modern user interfaces to computing systems have employed the widespread use of various interface software elements, for example, menus, windows (including forms), dialog boxes, controls, icons, colour, behaviours, and language. Usage and employment of some or all of these elements are dependent upon task-related determination of their suitability and appropriateness, and permit the composition of different interaction styles available to the user. The proper usage and employment of such elements can be the outcome of insightful interface design, and can lead to effective user interfaces. In terms of menu interface elements, Shneiderman (1998) maintains that users should be confident in making menu selections if these menus are designed in a comprehensible and distinctive manner. Bier (1991) argues that the user interface community strives to build interfaces that improve the quality of user interaction 'by effectively presenting information to the user and making it easy to act on and manipulate that information.'

Interaction styles such as form-filling, command entry using text-based input or graphical object selection, or direct manipulation all result in some form of dialogue between the user and the interface. Dialogue is bi-directional between the user and the interface, where, for example, a user's input method may take the form of a text-based command line entry, and the system's resultant output may occur using the on-screen display of a graphical element such as a message box containing a combination of graphical objects and/or text. Direct manipulation allows users to feel that they are directly controlling the objects represented on a computer's display (Bos, 1992). According to the principle of direct manipulation, an object on a computer screen's graphical user interface remains visible while a user performs physical actions on the object. As a user performs operations on the object, the impact of those operations on the object is immediately visible, usually on screen, as a feedback measure from the system to the user. For example, a user can move a file by using an input device to drag an icon that represents it from one location to another or can position a cursor in a text field by directly selecting or clicking the location where the cursor should be placed. Shneiderman (1998) affirms that the success of direct manipulation interfaces is 'indicative of the power of using computers in a more visual or graphic manner'.

The direct manipulation of on-screen objects, whether as the user-initiated selection of an item displayed on a menu or the mouse-controlled dragging of a file's icon into a folder's icon, is usually associated either with some form of change in appearance of that object, or on-screen movement involving that object. For example, dragging an icon across a display screen may necessitate the visual animated on-screen movement of that icon through software-driven graphical rendering, or selecting an item from a menu may result in that tem 'blinking' on screen as visual feedback to the user. Such visual animated object feedback to the user may or may not increase the interface's usability (Dukart, 2001).

All computer systems employ the use of software-based user interface screen metaphors and symbols in an effort to represent abstract physical constructs to users in such a way as to increase the system's understandability and usability (Gershon et al., 1998; Harrison, Kurtenbach and Vicente, 1995; Vaughan, 1998). Metaphor and symbol use in user interfaces are steps toward the invisible enhancement of the world as represented by user interfaces. Araya (1995) describes this goal as a move toward ubiquitous computing, where interface metaphors are made invisible to, or hidden from, the user.

Most modern computerised systems provide a graphical user interface comprised of various categories of metaphor in conjunction with textual elements (Olfman and Mandviwalla, 1994), so as to offer high levels of interface usability through good design. Modern graphical interface environments, using capable graphics and high quality screens offer a wider variety of metaphorical on-screen representations than possible in other interface approaches (for example, command-line interfaces). Marcus (1993) classifies metaphors as mainly either icons or symbols, describing icons as objects ‘that communicate by virtue of their inherent physical characteristics that make them look like the objects to which they refer’, and symbols as metaphors that are ‘understood on the basis of convention, having little or no inherent meaning of their own. They may not look anything at all like the objects, structures, or processes they represent’. Marcus (1993) states that metaphor design will be one of the important challenges for future user interface creation, because ‘communication between humans is normally filled with metaphorical references.’ Advances in computer graphics and the expertise of developers have helped to enable the evolution of more diverse methods of interaction for user interfaces (Barfield, 1993). Some of these methods have allowed for the inclusion of interaction metaphors capable of the emulation of more human interactive environments, for example, overlapping of screen objects, direct manipulation of screen objects (Bauersfeld and Slater, 1991; Derthick, Kolojejchick and Roth, 1997; Myers, Hollan, Cruz, Bryson, Bulterman, Catarci, Citrin, Glinert, Grudin and Ioannidis, 1996), drop shadows on screen objects, moving imagery and animations (Morrison and Vogel, 1998), and user-controlled abstraction.

Shneiderman (1998) argues that wherever possible, the operations available to a user should be based on physical metaphors (Carroll and Rosson, 1987), whose functional usability is learned through user analysis, assumption, and innate or learned interpretation. Metaphors used in modern computer systems include the 'desktop' similes of graphical user interfaces, composed of contextual groupings of related elements together with a set of actions or 'relations' a user can perform on the metaphor (Preece et al., 1994). On-screen icons assist users to visualise aspects of system functionality accessed via the user interface through interaction with such icons. On-screen software-based graphical icons need to be recognisable by users as associated with some aspect of system functionality accessed via the interface (McDougall, Curry and de Bruijn, 1999). Objects such as iconic representations of folders containing documents, or three-dimensional rooms can map to virtual three dimensional metaphorical spaces in multimedia environments, but may involve some distortion of representation to culminate in a metaphor that is more usable (Leung and Apperley, 1994). For example, many window-based GUIs represent folders on screen as tabbed fixed-size iconic rectangles. Such GUIs allow the visual representation of the nesting of folders inside one another. Although the real-world insertion or nesting of a folder into another (or many others) of equal size is physically unsound, the metaphorical representation overcomes this difficulty by avoiding the physical constraint and allowing the user to accept the distortion of the mapping as an acceptable compromise in return for a usable metaphorical icon.

2.2 Presenting data for decision making

Most traditional information systems use large screen displays such as PC screens to output and present data to users. Solutions to increase the usability of user interfaces on computer systems, to the display of information on screens, and to address the effort associated with the usage of large amounts of data need to be addressed by interface designers. Particularly where an information system uses and displays large amounts of data, such as spreadsheet applications or database- or web-based searches, ease of use and usefulness can be compromised, as can user perceptions towards the information system as workable and appropriate for certain tasks. Decision making is the performance of a task, that of making a particular decision (Bahl and Hunt, 1984). Decision quality, and the effort expende in making a decision, are central and important factors in decision making through their influence on decision behaviour (Payne, 1982; Todd and Benbasat, 1991; Vessey and Galletta, 1991). There is a need for research examining the best presentation of data for varying decision scenarios and personal decision styles and behaviours, which would have a direct applicability for managers in organisations. Clever usage of iconery and metaphors in addition to appropriate tabulated or graphical data display may address problematic issues in effective decision making.

3. Conclusions

Most iconic metaphors used in modern computing systems are visual, based on visual interpretation of that icon's meaning, through the human sense of vision. Gershon et al. (1998) comment that a key research problem is to discover new visual metaphors for representing sometimes abstract information, and that 'with effective visual interfaces we can interact with large volumes of data rapidly and effectively to discover hidden characteristics (Bos, 1992), patterns, and trends.' Visual metaphors engage with the user usually through only one of that user's five natural senses (Mynatt and Edwards, 1992). Strange then, that the visual representation of data can be icon-based or numeric, but that one format can mask the other. As an example, managerial decision making involves the use and manipulation of data and information – however, the quality of the decision may be reliant upon the way in which the data is presented. Where data have many attributes or possible values, and where there are a large number of variables to entertain, the most common ways for managers to present data for decision making involve either graphing the data or presenting the data as a table. The former involves the use of metaphors and perhaps iconery to represent data peaks, highs and lows, outliers, clustering, and so on. But typically the graphical representation of such are founded upon learned norms and expected behaviours, and involve simple bar-chart bars, pie chunks, or long or short lines of some form or another. Particularly since the advent of spreadsheet software and graphical user interfaces in the early '80s there have been many studies examining the effectiveness of such representation formats (as examples, see Benbasat, Dexter and Todd, 1986; Ives, 1982; Tractinsky and Meyer, 1999; Watson and Driver, 1983). On the other hand, there are decision-making scenarios and instances where tabulated data makes more sense, and the effectiveness of tabulated data as an enabler of effective decisions is well-discussed elsewhere (as examples, see Christie, Klein and Watters, 2004; Rao and Card, 1994; Watters, Duffy and Duffy, 2003; Zhang, Watters and Duffy, 2006).

With the advent of advanced graphical rendering and data representation 'options', there remains ambiguity on the relative efficacy of charts versus tables as means of representing data for decision making. Metaphor and symbol inclusion in computing interfaces have a paramount objective of increasing usability and, in decision-making scenarios, effecting optimal decisions. Ntuen (1996) states that existing graphic-based user interfaces that 'operate on active symbologies and icons assume the user's mental models to correlate with perceptual and cognitive levels of the task understanding'. Metaphors and symbols must be designed in a way to provoke positive emotive feelings (Kim and Moon, 1998) from users, so that the metaphors help to increase the usability of the interface from the user's point of view, and must lead to an increased accessibility for users by using and understanding the symbols and metaphors with ease (Dukart, 2001; Tractinsky, 1997). Although studies have explored data presentation for decision making (for example, see Acton, Golden and van der Heijden, 2005; Acton, Golden and van der Heijden, 2006; Acton, Golden and van der Heijden, 2007), there is a need for research into the relative advantages and appropriateness of graphical versus tabulated presentation of data for decision making, the appropriateness of distortive versus non-distortive techniques of aggregating or presenting large amounts of data, and a need for research that categorises the type and structure of data that would be best suited by either graphical or tabulated representation for analytical decision making. Further, there is a dearth of research examining the kinds of decision support tools that map to presentation formats – targeted tools such as decision aids that would enable the effective use of particular presentation formats by managers for decision making. While various studies have examined the efficacy of decision support tools for tabulated data, and other studies have examined the relative benefits of tabulated versus graphical presentation formats, there has been little categorization of the types of support mechanisms that may suit presentation format in such a way that managers can drill down through aggregated data to the underlying detail: whilst aggregated data such as that typically embodied in charts and summary tables can provide high abstract overviews of data, present changes in data over time, visualize trends in data and so on, the low level detail in underlying data may not be accessible through these formats without resort to other methods of data access. Tools with high usability that can support managers in facilitating movement from high to lower levels of data abstraction may be extremely beneficial for decision making.

References

Acton, T., Golden, W. and van der Heijden, H. (2005) *The Effectiveness of Decision Support Systems on Mobile Devices*, International Conference on Information Systems, Decision Support Systems Workshop, Las Vegas, Nevada, U.S.A., December 11.

Acton, T., Golden, W. and van der Heijden, H. (2006) *Mobile Interfaces for Decision Support*, In Creativity and Innovation in Decision Making and Decision Support, Vol. 1 (Eds, Adam, F., Brezillon, P., Carlsson, S. and Humphreys, P.) Ludic Publishing Ltd, London, pp. 340-356.

Acton, T., Golden, W. and van der Heijden, H. (2007) *Decision Support for Small Screen Information Systems*, IFIP 8.3 task force on learning from case studies in decision making and decision support (Ed, Adam, F.), University College Cork, Ireland, April 5/6.

Araya, A. A. (1995) *Questioning ubiquitous computing*, Proceedings of the 1995 ACM 23rd Annual Conference on Computer Science, Nashville, TN USA, February 28 - March 2, 1995, pp. 230-237.

Asahi, T., Turo, D. and Shneiderman, B. (1995) *Using treemaps to visualize the Analytic Hierarchy Process,* Information Systems Research, 6 (4), pp. 357-375.

Bahl, H. C. and Hunt, R. G. (1984) *Decision-Making Theory and DSS Design,* Data Base, 15 (4), pp. 10-14.

Barfield, L. (1993) *The User Interface - Concepts & Design,* Addison-Wesley, Suffolk.

Bauersfeld, P. F. and Slater, J. L. (1991) *User-oriented color interface design: direct manipulation of color in context*, Conference on Human Factors and Computing Systems, 1991, New Orleans, LA USA, April 27 - May 2, pp. 417-418.

Benbasat, I., Dexter, A. S. and Todd, P. (1986) *The Influence of Color and Graphical Information Presentation in a Managerial Decision Simulation.,* Human-Computer Interaction, 2 (1), pp. 65-92.

Benderson, B. and Hollan, J. (1994) *Pad++: A Zooming Graphical Interface for Exploring Alternate Interface Physics*, Proceedings of UIST Conference, pp. 17-26.

Bier, E. A. (1991) *EmbeddedButtons: documents as user interfaces*, Proceedings of the fourth annual ACM symposium on User interface software and technology, November 11 - 13, 1991, Hilton Head United States, November 11 - 13, 1991, Hilton Head United States, pp. 45-53.

Bos, E. (1992) *Some virtues and limitations of action inferring interfaces*, Proceedings of the fifth annual ACM symposium on User interface software and technology., Monteray, CA USA, November 15 - 18, pp. 79-88.

Brachtl, M., Slajs, J. and Slavik, P. (2001) *PDA based navigation system for a 3D environment,* Computers & Graphics, 25 (4), pp. 627-634.

Card, S., Robertson, G. and Mackinlay, J. (1991) *The Information Visualizer, an Information Workspace*, Proceedings of Computer-Human Interaction Conference, pp. 181-188.

Carroll, J. M. and Rosson, M. B. (1987) *Interfacing Thought: Cognitive Aspects of Human-Computer Interaction.,* MIT Press, Cambridge, MA.

Christie, J., Klein, R. M. and Watters, C. (2004) *A comparison of simple hierarchy and grid metaphors for option layouts on small-size screens,* International Journal of Human-Computer Studies, 60 (5-6), pp. 564-584.

Derthick, M., Kolojejchick, J. and Roth, S. F. (1997) *An interactive visual query environment for exploring data*, Proceedings of the 10th annual ACM symposium on User interface software and technology, Banff, Canada, October 14 - 17, pp. 189-198.

Dukart, J. R. (2001) *Making Your Site More Usable*, Vol. 2001 Office.com.

Gershon, N., Eick, S. G. and Card, S. (1998) *Information visualization,* Interactions, 5 (2), pp. 9-15.

Graham, M., Kennedy, J. and Benyon, D. (2000) *Towards a methodology for developing visualizations,* International Journal of Human-Computer Studies, 53 (5), pp. 789-807.

Harrison, B. L., Kurtenbach, G. and Vicente, K. J. (1995) *An experimental evaluation of transparent user interface tools and information content*, Proceedings of the 8th ACM symposium on User interface and software technology, November 15 - 17, 1995, Pittsburgh, PA USA, November 15 - 17, 1995, Pittsburgh, PA USA.

Ives, B. (1982) *Graphical User Interfaces for Business Information Systems,* MIS Quarterly, 6 (5), pp. 15-47.

Kamba, T., Elson, S. A., Harpold, T., Stamper, T. and Sukaviriya, P. N. (1996) *Using small screen space more efficiently,* Conference proceedings on Human factors in computing systems ACM Press, Vancouver, Canada, pp. 383-390.

Kim, J. and Moon, J.-Y. (1998) *Designing towards emotional usability in customer interfaces--trustworthiness of cyber-banking system interfaces,* Interacting with Computers, 10 (1), pp. 1-29.

Kumar, H. P., Plaisant, C. and Shneiderman, B. (1997) *Browsing hierarchical data with multi-level dynamic queries and pruning,* International Journal of Human-Computer Studies, 46 (1), pp. 105-126.

Lamping, J., Rao, R. and Piroli, P. (1995) *A Focus+Context Technique Based on Hyperbolic Geometry for Visualizing Large Hierarchies*, Proceedings of Computer-Human Interaction Conference.

Leung, Y. K. and Apperley, M. D. (1994) *A review and taxonomy of distortion-oriented presentation techniques,* ACM Transactions on Computer-Human Interaction, 1 (2), pp. 126-160.

Mackinley, J. D., Robertson, G. G. and Card, S. K. (1991) *The Perspective Wall: Detail and context smoothly integrated,* Proceedings of CHI ACM Press, pp. 173-179.

Marcus, A. (1993) *Human communications issues in advanced UIs,* Communications of the ACM, 36 (4), pp. 100-109.

McDougall, S. J. P., Curry, M. B. and de Bruijn, O. (1999) *Measuring symbol and icon characteristics: Norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols,* Behavior Research Methods Instruments & Computers, 31 (3), pp. 487-519.

Mitta, D. A. (1990) *A Fisheye Presentation Strategy: Aircraft Maintenance Data*, Proceedings of Interact Conference, pp. 875-885.

Morrison, J. and Vogel, D. (1998) *The impacts of presentation visuals on persuasion,* Information & Management, 33 (3), pp. 125-135.

Myers, B., Hollan, J., Cruz, I., Bryson, S., Bulterman, R., Catarci, T., Citrin, W., Glinert, E., Grudin, J. and Ioannidis, Y. (1996) *Strategic directions in human-computer interaction,* ACM Computing Surveys, 8 (24), pp. 794-809.

Mynatt, E. D. and Edwards, W. K. (1992) *Mapping GUIs to auditory interfaces*, Proceedings of the fifth annual ACM symposium on User interface software and technology, Monteray, CA USA, November 15 - 18, pp. 61-70.

Ntuen, C. A. (1996) *A theory of command language dialogue for a knowledge-based human-computer interaction,* International Journal of Human-Computer Interaction, 8 (2), pp. 145-164.

Olfman, L. and Mandviwalla, M. (1994) *Conceptual Versus Procedural Software Training for Graphical User Interfaces: A Longitudinal Field Experiment,* MIS Quarterly, 18 (4), pp. 405-426.

Payne, J. W. (1982) *Contingent Decision Behavior,* Psychological Bulletin, 92 (2), pp. 382-402.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S. and Carey, T. (1994) *Human-Computer Interaction,* Addison-Wesley, Reading, MA., USA.

Rao, R. and Card, S. K. (1994) *The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus+Context Visualization for Tabular Information*, Proceedings of CHI Conference, pp. 318-322.

Robertson, G. G. and Mackinlay, J. D. (1993) *The Document Lens*, Proceedings of UIST Conference.

Shneiderman, B. (1998) *Designing the User Interface,* Addison-Wesley.

Shneiderman, B., Byrd, D. and Croft, W. B. (1998) *Sorting out searching: a user-interface framework for text searches,* Communications of the ACM, 41 (4), pp. 95 - 98.

Todd, P. and Benbasat, I. (1991) *An Experimental Investigation of the Impact of Computer Based Decision Aids on Decision Making Strategies,* Information Systems Research, 2 (2), pp. 87.

Tractinsky, N. (1997) *Aesthetics and apparent usability: empirically assessing cultural and methodological issues*, Conference Proceedings on Human Factors in Computing Systems, Atlanta, GA USA, March 22 - 27, pp. 115-122.

Tractinsky, N. and Meyer, J. (1999) *Chartjunk or Goldgraph? Effects of Presentation Objectives and Content Desirability on Information Presentation,* MIS Quarterly, 23 (3), pp. 397-420.

Turetken, O. and Sharda, R. (2004) *Development of a fisheye-based information search processing aid (FISPA) for managing information overload in the web environment,* Decision Support Systems, 37 (3), pp. 415-434.

Vaughan, M. W. (1998) *Testing the boundaries of two user-centered design principles: Metaphors and memory load,* International Journal of Human-Computer Interaction, 10 (3), pp. 265-282.

Vessey, I. and Galletta, D. (1991) *Cognitive Fit: An Empirical Study of Information Acquisition,* Information Systems Research, 2 (1), pp. 63-84.

Watson, C. J. and Driver, R. W. (1983) *The Influence of Computer Graphics on the Recall of Information,* MIS Quarterly, 7 (1), pp.

Watters, C., Duffy, J. and Duffy, K. (2003) *Using large tables on small display devices,* International Journal of Human-Computer Studies, 58 (1), pp. 21-37.

Yang, C. C., Chen, H. and Hong, K. (2003) *Visualization of large category map for Internet browsing,* Decision Support Systems, 35 (1), pp. 89-102.

Zhang, R., Watters, C. and Duffy, J. (2006) *Using Overview Style Tables On Small Devices*, 14th European Conference on Information Systems, Gothenburg, Sweden, July 12 - 14.